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Herring Run Sewershed Evaluation Study Plan
Project 1001

Sewershed Study and Plan Report
Sanitary Sewer Overflow Consent Decree
Civil Action No. JFM-02-1524

June 2009

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Executive Summary

On September 30, 2002, the City of Baltimore (City) entered into a Consent Decree (CD) with the United States Environmental Protection Agency (EPA), the State of Maryland Department of the Environment (MDE) and the Department of Justice (DOJ). The objective of Paragraph 9 of the CD is to complete a series of "Collection System Evaluation and Sewershed Plans". This Sewershed Study and Plan details the evaluation of the Herring Run Sewershed.

Herring Run is one of eight sewersheds located within the City of Baltimore. The sewershed includes approximately 1.57 million linear feet (LF) of gravity sewer ranging from 6- to 72-inches in diameter, approximately 7,200 public sector manholes, 3 sets of inverted siphons; the Quad Avenue Wastewater Pumping Station and 2,200 LF of associated existing force main.

Much of the sewershed's collection system was constructed in the 1930s and 1940s. The collection system includes two independent conveyance sub-systems. One sub-system conveys flow from the Chinquapin Run and Tiffany Run Interceptors, which serve the western portion of the sewershed, to the Herring Run Interceptor. Flow from the Belmar, Moore's Run and Biddison Run Interceptors, which serve the eastern portion of the sewershed, convey flow to the Lower Moore's Run Interceptor. Flow in the Lower Moore's Run Interceptor is conveyed through the Moore's Run Siphons to the Herring Run Interceptor. Flow in the Herring Run Interceptor is conveyed to the Outfall Relief Interceptor, which eventually discharges to the Back River Waste Water Treatment Plant (WWTP) for processing. The Herring Run Interceptor conveys approximately 80-percent of the total sewershed collection system wastewater flow. The second sub-system includes the Herring Run Low Level and Moore's Run Low Level Interceptor, which convey flow from the eastern border of the sewershed to the Quad Avenue Wastewater Pumping Station. Approximately 20-percent of the total sewershed collection system wastewater flow is pumped from the station into the Quad Avenue Force Main, which discharges into the Outfall Relief Interceptor.

In accordance with the CD, the following items have been completed for the Herring Run Sewershed Study and Plan:

- Evaluated the effectiveness of the construction projects completed pursuant to Paragraph 8 of the CD using rainfall and flow monitoring data, as well as the hydraulic model developed in accordance with Paragraph 12 of the CD. Based on a comparison of pre- and post-flow monitoring data, there has been a significant volume reduction in Sanitary Sewer Overflows (SSOs) in the sewershed since the Paragraph 8 projects were completed.

- Presented the results of the rainfall and flow monitoring, as well as smoke and dyed water testing, conducted in the sewershed.

- Identified deficiencies discovered during the collection system inspections, which included inspection of all gravity sewers having a diameter of eight inches or greater using closed circuit television (CCTV) inspection and inspection of all manholes and other appurtenances within the sewershed.

- Identified rehabilitation and other corrective actions taken, or proposed to be taken, to address the deficiencies identified during the evaluation of the sewershed.

- Described the decision-making criteria used to select future corrective action.

- Proposed a plan and schedule for future evaluation of the collection system within the sewershed.

- Proposed a plan and schedule for implementing rehabilitation and other corrective actions determined necessary either to correct deficiencies identified during the collection system evaluation or to ensure operation of the collection system.

- Proposed a plan and schedule for eliminating those identified physical connections between the sanitary sewer collection system and the storm water collection system.

- Determined the range of storm events for which the collection system in its existing condition can convey peak flows without the occurrences of SSO's.

- Predictably determined the range of storm events for which the collection system will be able to convey peak flows without the occurrence of SSO's assuming completion of the Paragraph 8 construction projects and completion of the proposed rehabilitation and other corrective action projects recommended in this Sewershed Plan

- Certified the Geographic Information System (GIS) described in Paragraph 14 of the CD.

As required by the CD, the Sewershed Plan identifies specific improvements or other corrective actions needed to address structural deficiencies to reduce rainfall dependent inflow and infiltration (RDII) contributing to SSO's, address hydraulic deficiencies identified during the hydraulic analyses, and address other deficiencies that contribute to SSO's.

As part of the sewershed study, the City developed a condition and criticality protocol that provides the framework for a rehabilitation strategy based on criticality (consequences of failure) and condition (probability of failure) ratings of 1 through 5. Assets whose failures can impact the community or environment and whose condition is the poorest received a higher rating and will receive attention sooner. Assets that receive a lower rating will receive some level of regular monitoring but no immediate action or rehabilitation. Five levels of prioritization were developed based on the combination of condition and criticality as shown in the matrix in Figure ES-1:

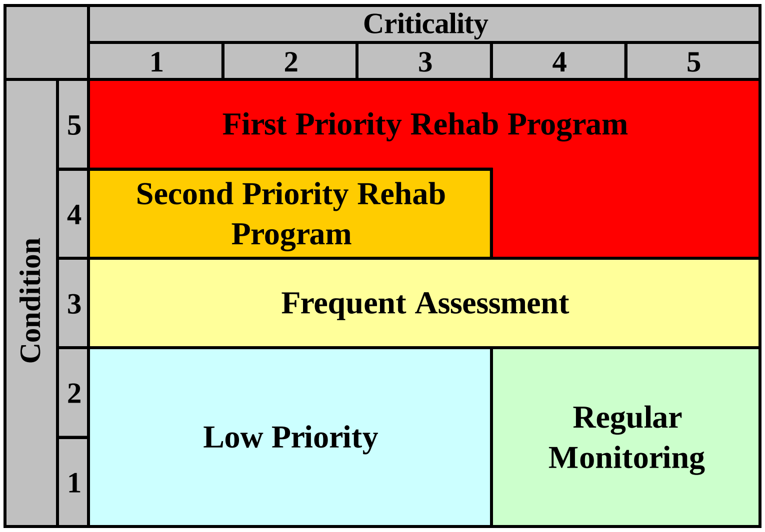


Figure ES-1: Condition and Criticality Matrix

Prioritization of asset rehabilitation projects and other corrective actions were developed considering that all proposed improvements required to eliminate SSO's must be completed before January 1, 2016, as stipulated in the CD. The proposed improvements include elimination of identified SSO structures, rehabilitation of "First and Second Priority Rehabilitation Program" manholes and sanitary sewers, and completion of the required hydraulic improvements. The proposed improvement projects and the estimated costs to complete these repairs are summarized in the following table:

Table ES-1: Proposed Improvement Projects Summary (cost in millions of 2008 dollars)

First and Second Priority Sewer Rehabilitation			
Rehabilitation Item	**Length/Count**		**Est. Cost**
Manhole Rehabilitation/Replacement	152	Ea.	$0.80
Cured-In-Place-Pipe Lining	82,256	LF	$7.31
Sewer Point Repair (10' Repair)	8,750	LF	$4.73
Sewer Replacement (> 10' Repair)	7,092	LF	$3.14
Sewer Point Repair and Cured-In-Place-Pipe Lining	500 EA & 11,433	LF	$1.36
Sewer Replacement and Cured-In-Place-Pipe Lining	76 LF & 408	LF	$0.06
	Sub-Total Estimated Cost:		$17.40
Sewer - Hydraulic Improvements			
Rehabilitation Item	**Length/Count**		**Est. Cost**
8-Inch to 30-Inch Cured-In-Place-Pipe Lining	15,718	LF	$ 1.48
8-Inch to 12-Inch Pipe Replacement	4,177	LF	$ 3.13
15-Inch to 36-Inch Pipe	4,862	LF	$ 4.86
Manhole Rehabilitation/Replacement	103	Ea.	$ 0.54
Equalization Tank	3,600,000	MG	$ 30.67
	Sub-Total Estimated Cost:		$ 40.68
	Total Estimated Cost:		**$58.08**

Inspection data for those manholes and sewers that received higher condition and criticality rating scores were reviewed. Those deficiencies that require corrective actions were recommended for inclusion in the First and Second Priority corrective action plan. These repairs include the rehabilitation or replacement of 152 manhole structures, installation of approximately 82,300 LF of cured-in-place-pipe (CIPP) liner, approximately 8,750 LF of point repairs, approximately 7,100 LF of sewer replacement and various quantities of point repair/CIPP and sewer replacement/CIPP combinations for deteriorated sewer located through the sewershed.

The recommended hydraulic improvements include a 0.6 million gallon offline storage tank and a comprehensive inflow and infiltration (I/I) reduction program in the Chinquapin Run sub-sewershed. A separate I/I reduction program and a new 10-inch diameter sewer are recommended in the Tiffany Run sub-sewershed. In the Herring Run West Branch sub-sewershed, a new 15-inch diameter parallel sewer is recommended. Miscellaneous 10 and 12-inch diameter sewer replacements with larger diameter sewers are recommended in the Upper Herring Run sub-sewershed. A 3.0 million gallon offline storage tank is recommended in the Herring Run sub-sewershed. Miscellaneous manhole sealing and 10-inch diameter sewer replacement are recommended for the Lower Herring Run and Moore's Run sub-sewersheds, respectively.

It should be noted that the interrelationship between the City's sewersheds, known as boundary conditions, must be carefully considered before significant hydraulic repairs are completed. Six sewersheds are connected and hydraulically interdependent, creating "boundary" conditions that must be defined and considered for hydraulic modeling. Under Contract 1015, the City is developing of a system-wide model that will be refined and improved as the individual sewershed studies complete calibration of their respective models. This Plan provides recommended improvements that should be implemented by the City in accordance with the schedule provided. However, the Plan should not be considered final and may require amendment once the system-wide hydraulic model is completed and simulations are performed.

As required by Paragraph 9.C.xii of the CD and under other contracts, the City will also implement continuous operation and maintenance enhancement efforts within the sewershed. These programs will be comprehensive, system-wide initiatives that will include a long-term flow monitoring plan, a sewer cleaning program CCTV and manhole inspection programs and root and grease control programs.

1.0 Project Description

1.1 Project Background

On September 30, 2002 the City of Baltimore (City) entered into a Consent Decree with the U.S. Environmental Protection Agency (EPA), the U.S. Department of Justice (DOJ) and the Maryland Department of the Environment (MDE) to eliminate all wet weather sanitary sewer overflows. In accordance with the Consent Decree, the City of Baltimore Department of Public Works began collection system evaluation and sewershed studies of the entire wastewater collection system (as defined in Article VI Remedial Measures, Paragraph 9 of the Consent Decree). In November 2006, the City contracted with Black & Veatch Corporation (Black & Veatch) to complete an evaluation study for the Herring Run Sewershed. This study report details the evaluation of the Herring Run Sewershed, one of eight Baltimore City sewersheds.

The Herring Run Sewershed Study, City of Baltimore Project 1001, consists of various investigative and analytical activities as required by the Consent Decree, including:

i. Flow monitoring data analysis
ii. Sewer manhole inspection
iii. Sewer closed circuit television (CCTV) video inspection
iv. Smoke testing
v. Dye flood and dyed-water testing
vi. Updating the City's wastewater Geographic Information System (GIS)
vii. Water-In-Cellar complaint review
viii. Projection of current and future base sanitary flow
ix. Preparation, calibration and validation of a hydraulic model
x. Critical sewer system component identification
xi. Condition assessment and criticality rating of the sewer collection system components
xii. Development of a long-term rehabilitation and corrective action plan
xiii. Cost estimate preparation

The Herring Run Sewershed includes approximately 1.57 million linear feet (LF) of gravity sewer ranging from 6- to 72-inches in diameter, approximately 7,202 public sector manholes, 3 sets of inverted siphons; the Quad Avenue Wastewater Pumping Station and 2,200 LF of associated existing force main.

The sewershed study elements are defined in the Paragraph 9.C of the Consent Decree and are summarized as follows:

i. Evaluation of the effectiveness of completed and proposed sanitary sewer projects (identified in Paragraph 8.B of the Consent Decree)
ii. Identification of sewer collection deficiencies discovered during inspections
iii. Identification of rehabilitation and other corrective actions performed by the City to address deficiencies identified in Item ii
iv. Recommendation of proposed rehabilitation and other corrective actions, developed in accordance with guidance provided by the City, to address deficiencies identified in Item ii
v. Description of decision making criteria for selection of future corrective action
vi. Development of a plan and schedule for future wastewater collection system evaluation

vii. Development of a plan and schedule for implementation of rehabilitation and other corrective action deemed to be necessary to address deficiencies identified in Item ii or to ensure adequate operation of the wastewater collection system
viii. Preparation of a prioritization plan for the proposed corrective actions identified in Item vii.
ix. Preparation of cost estimates for proposed corrective actions identified in Item vii.
x. Preparation of a plan and schedule for eliminating physical connections between sanitary sewer and storm drains
xi. Determination of storm event range for which peak flows can be conveyed without occurrence of sanitary sewer overflows (SSOs) in the existing wastewater collection system
xii. Identification of model components that have the potential to cause or contribute to overflows
xiii. Determination of the range of storm events for which peak flows can be conveyed without occurrence of SSOs once the recommended construction projects are in place
xiv. Presentation of rainfall and flow monitoring analysis results
xv. Description of the quality assurance and quality control analyses performed for various field activities
xvi. Quantification of inflow and infiltration (I/I) and identification of I/I sources
xvii. Description of additional data collection activities that will continue after completion of rehabilitation and corrective action identified in Item vii
xviii. Certification that the GIS is functional in accordance with Paragraph 14.B of the Consent Decree

The content and structure of this Sewershed Study Report have been established to address each of the sewershed study and plan elements required under the Consent Decree.

1.2 Previous Study

Prior to the Consent Decree, a Herring Run sewershed study (City of Baltimore Project 635), was completed by George, Miles & Buhr, LLC, under contract with the City of Baltimore. The study included flow metering, hydraulic modeling and limited field investigations. The pipe and node data recorded in the hydraulic model was developed based on available record drawings and information provided by the City of Baltimore Wastewater Analyzer's Office. This model was later updated by the City's Technical Consultant using available record drawings and provided to Black & Veatch.

1.3 Purpose of Sewershed Study

The Herring Run Sewershed study contributes to the City's compliance with the Clean Water Act and Title 9, Subtitle 3 of the Environment Article, Annotated Code of Maryland and the regulations promulgated thereunder and all terms and conditions of the Back River and Patapsco Wastewater Treatment Plants' National Pollutant Discharge Elimination System (NPDES) permits. Sanitary Sewer overflows and dry weather overflows have been evaluated for elimination in the Herring Run Sewershed collection system through development and implementation of the measures set forth in Paragraphs 8 through 15 of the Consent Decree. Construction projects 12 through 16, as identified in Appendix D of the Consent Decree, have been completed by the City. All SSO structured listed in Appendix C have been eliminated. Illegal stormwater or sewer connections are identified and proposed for elimination. Potential rainfall-dependent infiltration and inflow (RDII) sources from privately owned customer service laterals have been identified through an extensive smoke test program. The City's GIS has been updated to be accurate, fully functional and capable of displaying the information described in Paragraph 14, Item b.i though iv of the Consent Decree.

1.4 Description of the Sewershed and Sub-Basins

The Herring Run Sewershed is one of eight sanitary sewersheds located within the City of Baltimore as shown in Figure 1.4.1. The sewershed is located in the northeast corner of the City and extends north and east into Baltimore County (County); however, the study area covers only that portion of the sewershed located within the City limits, approximately 17.9 square miles. The majority of the sewershed's land usage is residential; however, there are commercial corridors located along the primary and arterial routes and in the southern portion of the sewershed.

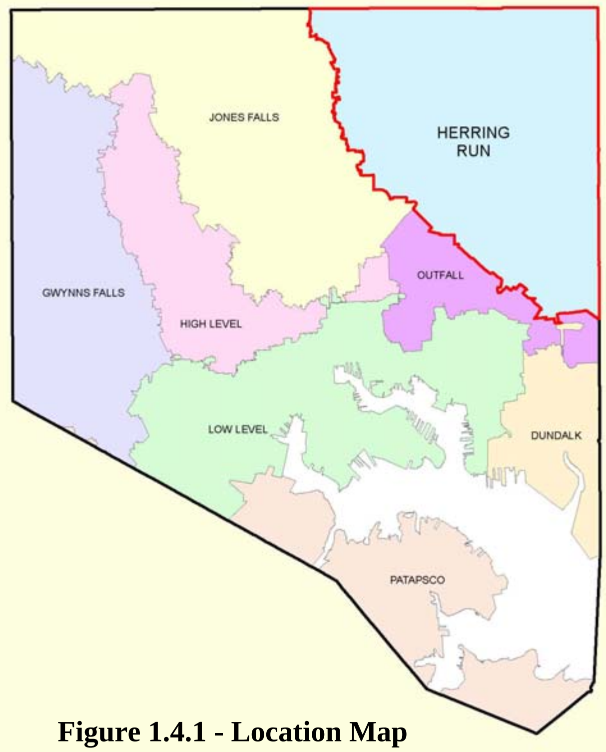


Figure 1.4.1 - Location Map

The sanitary collection system conveys flow to the Outfall Interceptors, which discharge into the Back River Wastewater Treatment Plant.

The Herring Run sewershed consists of 13 sub-sewersheds. The boundaries for each of the sub-sewershed are depicted on Map 1.4.1. In general, the wastewater collection system consists of two separate sub-systems. The wastewater flow generated from the eastern half of the sewershed (approximately 20-percent of the base flow) is conveyed to Quad Avenue Wastewater Pumping Station, which discharges to the Outfall Interceptor. The western half of the sewershed (approximately 80-percent of the base flow) is conveyed by gravity sewer to the Lower Herring Run Siphons, which discharge into the Outfall Interceptor. A brief description of the primary interceptor serving each of the 13 sub-sewersheds is provided below:

The **Herring Run Interceptor, West Branch (HRWB)** serves an area located along the northern border of the sewershed. Approximately 21,000 lf of sewer, serving approximately 0.4 square miles of primarily residential housing, discharges into the West Branch Interceptor. The tributary area extends into the County; however, this report discusses only the portion of the sewershed within the City limits. As shown in Figure 1.4.2, the proposed work for Sanitary Contract 856 will rehabilitate approximately 6,000 linear feet of the interceptor using a cured-in-place-pipe (CIPP) liner.

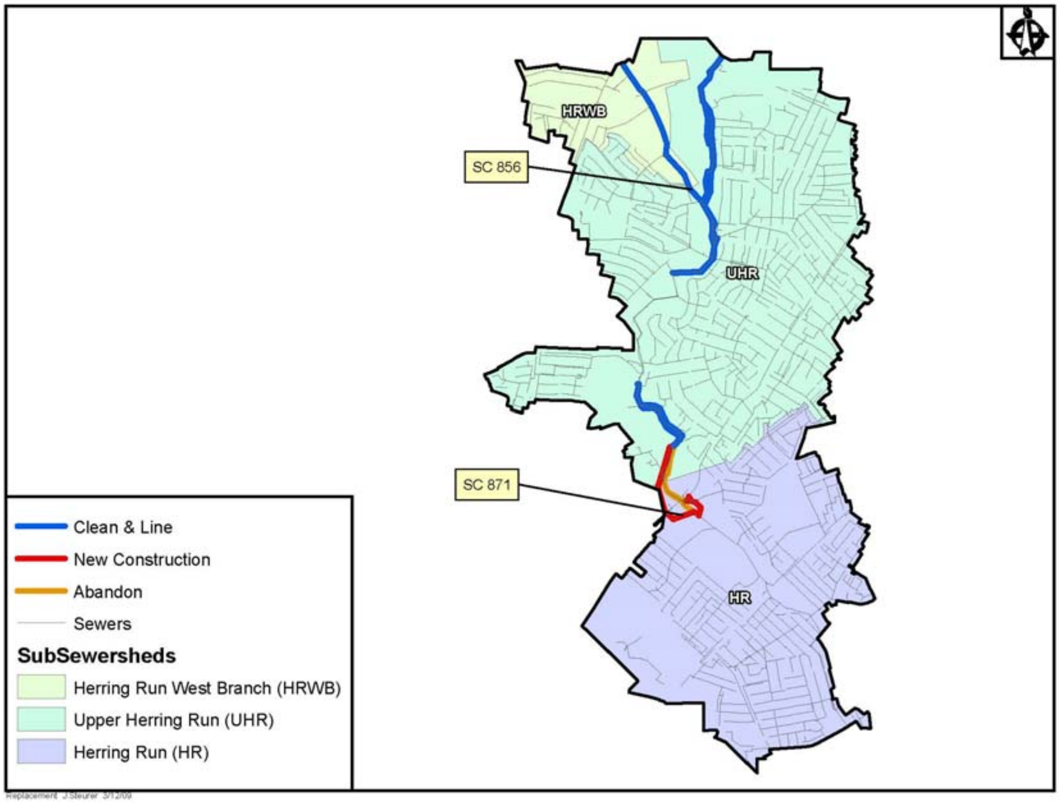


Figure 1.4.2 – Sanitary Contract Construction Locations

The **Upper Herring Run Interceptor (UHR)** runs parallel to the Herring Run stream. It is the primary interceptor to convey wastewater flow from the upper section of the sewershed and from Baltimore County. A portion of the interceptor from the City/County line to Harford Road consists of parallel interceptors. Approximately 244,000 lf of sewer, serving approximately 3.1 square miles of primarily residential development discharges into these interceptors. The downstream sections of the interceptors have historically experienced overflows due to various pipe and manhole structural failures. Additionally, based on previously-completed closed-circuit television (CCTV) inspections prior to the Consent Decree, significant base infiltration was observed entering the interceptor through various sewer defects and pipe joints. As shown in Figure 1.4.2, the proposed work for Sanitary Contract 871 will relocate 2,900 lf of interceptor.

The **Herring Run Interceptor (HR)** serves the central portion of the sewershed and is one of the primary interceptors to convey wastewater flow from the northern portion to the southern portion of the sewershed. The tributary area includes approximately 183,000 lf of sewer that serves 1.9 square miles of residential and commercial development. The interceptor also conveys flow from three upstream interceptors (Upper Herring Run, Tiffany Run and Chinquapin Run Interceptors).

The **Lower Herring Run Interceptor (LHR)** includes approximately 13,000 lf of tributary sewer that serves 1.2 square miles of residential, commercial and light industrial development. Approximately 80-percent of the base flow collected in the sewershed is conveyed by the Lower Herring Run Interceptor to the Outfall Interceptor. The Lower Herring Run Interceptor includes the High Level Herring Run Siphons, which consists of twin 36-inch and one 24-inch diameter siphons and the Lower Herring Run Siphon, which consists of twin 54-inch and one 24-inch diameter siphons. The Lower Herring Run Siphons discharge into the Outfall Relief Interceptor. A branch of the Lower Herring Run Interceptor, known as the Moore's Run Siphon (reference Sanitary Contract 843 in Section 2.2), consists of twin 22-inch and twin 36-inch diameter siphons.

The **Chinquapin Run Interceptor (CR)** serves the northwest portion of the sewershed. Approximately 196,000 linear feet of sewer serving 2.2 square miles of tributary area discharges into the Chinquapin Run Interceptor. The tributary area extends into the County; however, this report discusses only that area located within the City limits.

The **Tiffany Run Interceptor (TR)** serves the western border of the sewershed. The tributary area consists of approximately 1.9 square miles of primarily residential housing. The Montebello Water Treatment Plant is located in the tributary area; however, the plant backwash does not currently discharge into the wastewater collection system. Based on information provided by the City, there are no future plans to discharge backwash into the wastewater collection system. Approximately 234,000 lf of sewers discharge into the Tiffany Run Interceptor.

The **Moore's Run Interceptor (MR)** and **Belmar Interceptor (BE)** convey wastewater flow generated from the northeast quadrant of the sewershed. Approximately 1.9 and 0.8 square miles (including 204,000 lf and 100,000 lf of sewer, respectively) of residential development are served by the Moore's Run and Belmar Interceptors, respectively.

The **Biddison Run Interceptor (BR)** conveys wastewater flow generated from approximately 0.6 square miles of residential development. Approximately 88,000 lf of sewer discharges into the Biddison Run Interceptor.

The **Lower Moore's Run Interceptor (LMR)** and **Moore's Run Low Level Interceptor (MRLL)** are two of the primary interceptors to convey wastewater flow from the northern to southern portions of the sewershed. Approximately 0.6 and 1.5 square miles (or 48,000 and 66,000 lf of sewer) of residential development is served by the Lower Moore's Run and Moore's Run Low Level Interceptors, respectively.

The **Herring Run Low Level Interceptor (HRLL)** serves approximately 1.5 square miles of residential and light industrial development. Approximately 71,000 lf of sewer discharges into the Herring Run Low Level Interceptor, which conveys flow to the Quad Avenue Wastewater Pumping Station.

The **Quad Avenue Force Main (QA)** conveys wastewater flow from the Quad Avenue Pumping Station to the Outfall Relief Interceptor. The single 36-inch diameter force main measures approximately 2,200 lf and is the only means to convey flow from the wastewater pumping station. Approximately 3,000 lf of sewer servicing 0.1 square miles of light commercial development discharges directly to the pumping station. The Quad Avenue Pumping Station service area includes areas tributary to the Herring Run Low Level Interceptor and the Moore's Run Low Level Interceptor and some small tributary area located in the County.

The sub-sewersheds are divided into flow meter basins and Sewer Services Areas for hydraulic modeling purposes (reference Section 5).

1.5 Collection System Components and Attributes

The wastewater collection system components that are included in this sewershed evaluation include:

i. Gravity sewers that are 8-inch diameter and larger
ii. Sewer appurtenances including manholes, junction chambers, siphons, etc.
iii. Quad Avenue Wastewater Pumping Station
iv. Quad Avenue force main

The Quad Avenue Wastewater Pumping Station, located at 701 North Point Road, was rehabilitated in April 2004 under City of Baltimore Contract 9505. The Quad Avenue force main parallels North Point Road and discharges into the Outfall Relief Interceptor. The current station configuration includes the following pertinent attributes:

i. Three dry pit submersible wastewater pumps with variable speed control. Each pump has a capacity of 7,000 gpm at 74.5 total design head (TDH)/200 horsepower motor.
ii. Primary design point consisting of two pumps operating at 14,000 gpm/74.5 total design head
iii. 500 kilowatt standby diesel generator
iv. Estimated wet well storage time of 1.5 hours at typical flow rates
v. New piping installed to accommodate future temporary bypass pumping

The Quad Avenue Force Main, constructed under City of Baltimore Sanitary Contract 574 in 1973, is 36-inch diameter prestressed concrete cylinder pipe. No known rehabilitation work has been performed on the force main. Section 4.7 provides a summary of the force main condition assessment completed for this report.

2.0 Effectiveness of Paragraph 8 Construction Projects

In accordance with Paragraph 8 and Appendix D of the Consent Decree, the City completed a number of sewer construction projects in the Herring Run sewershed to eliminate engineered sanitary sewer overflow (SSO) locations. The project locations are shown on Map 2.0.1.

2.1 Engineered SSO Locations

A total of seven engineered SSO structures were constructed in the Herring Run Sewershed. The SSO structures included:

SSO 88	SSO 94	SSO 119
SSO 92	SSO 109	
SSO 93	SSO 118	

These structures were designed to relieve the wastewater collection system and overflow in the event of surcharge caused by hydraulic capacity limitations. Figure 2.1.1 shows the location of the engineered SSO structures located in the Herring Run Sewershed.

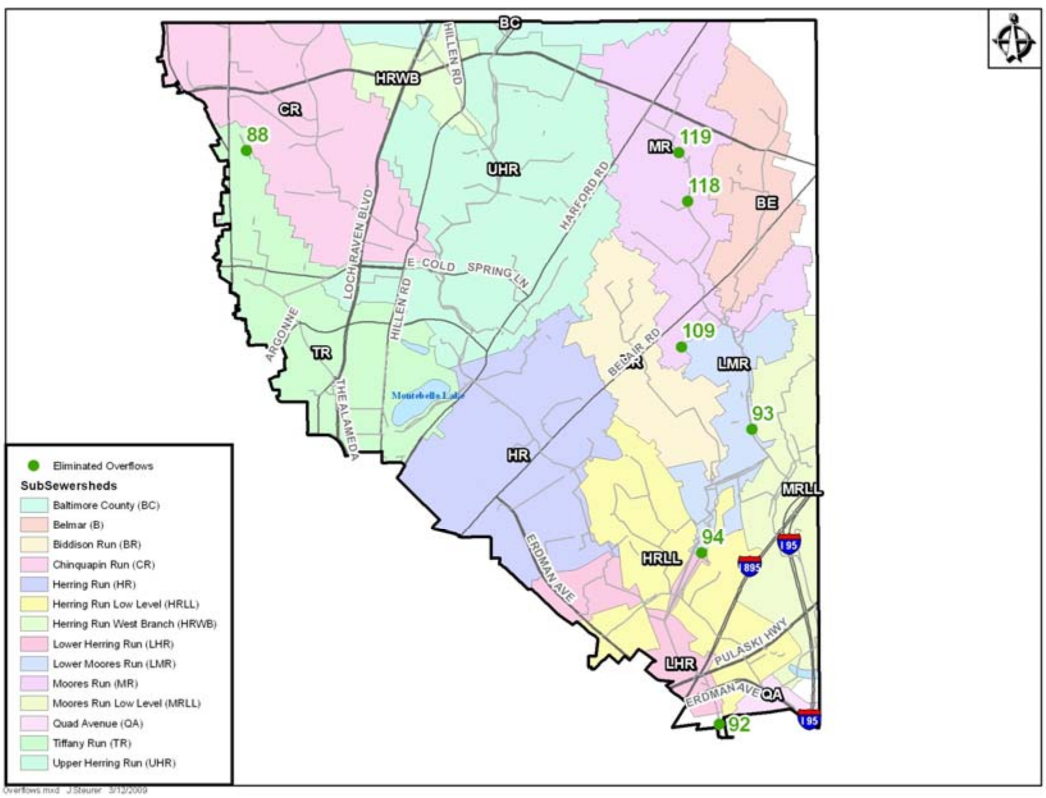


Figure 2.1.1 – Location of Engineered SSOs in the Herring Run Sewershed

2.2 Construction Projects

The Paragraph 8 projects located in the Herring Run Sewershed were completed to increase hydraulic capacity and/or eliminate engineered constructed sanitary sewer overflows. A summary of the Paragraph 8 projects completed in the Herring Run Sewershed is provided in Table 2.2.1.

Table 2.2.1 - Paragraph 8 Projects in the Herring Run Sewershed

CD Project ID No.	Sanitary Contract No.	Sub-Sewershed	Description	Actual Completion Date	SSOs Eliminated
12	SW 7746	Moore's Run	Increase pipe size for 7,200lf of exist. interceptor to 18" to	April 2005	118 & 119
12	SW 7751	Moore's Run/Lower Moore's Run		September 2005	118 & 119
13	SC 801	Lower Moore's Run	Increase pipe size for 10,600lf of exist. interceptor to 42" to 48" diam.	January 2008	93
13	SC 843	Lower Moore's Run/Lower Herring Run	Increase pipe size of exist. Siphons to 36" diam.	January 2008	94
14	SC 817	Moore's Run	Increase pipe size for 3,900lf of exist. interceptor to 18" to 21" diam.	October 2005	118 & 119
15	On-Call	N/A	Assess hydraulic capacity and design improvements for areas adjacent to overflows	June 2003	88 & 109
16	SC 830	Quad Avenue	Clean and inspect Low Level Herring Run Siphons. Abandon exist. drain vault	January 2004	92

2.3 Pre- and Post-Construction Flow Monitoring

Following the signing of the CD in September 2002, the City of Baltimore implemented a flow monitoring program in early 2003 to measure the flow at the seven engineered SSO locations in the Herring Run Sewershed. As indicated in Section 2.2, seven construction projects were at various stages of design or construction at the time the flow monitoring began. These seven projects were designed to improve or provide additional hydraulic capacity and to eliminate the seven SSO structures in the Herring Run Sewershed.

Because of the timetables of the construction projects and of the flow monitoring program, pre and post-construction flow data is available only for SSO 119. Construction projects to eliminate SSO 88 and SSO 109 began before the flow monitoring program. SSO 92 was a siphon blow off not conducive to flow monitoring, and was eliminated when the siphon was replaced with a new gravity interceptor with Project SC 830. SSO 93 and SSO 94 were eliminated by Projects SC 801 and SC 843 respectively and post construction flow monitoring was waved. SSO 118 was located in the same interceptor downstream from SSO 119, and was eliminated under SC 817.

Due to the circumstances explained above, the efficacy of the construction projects cannot be assessed readily with pre and post-construction flow monitoring data. However, an assessment can be made at SSO #119. Flow data for SSO #119 shows a significant hydraulic improvement post construction. Figure 2.3.1 below indicates regular backwater conditions and downstream SSO activity before construction (top scattergraph), and a significant increase in system capacity and no SSO activity after construction (bottom scattergraph).

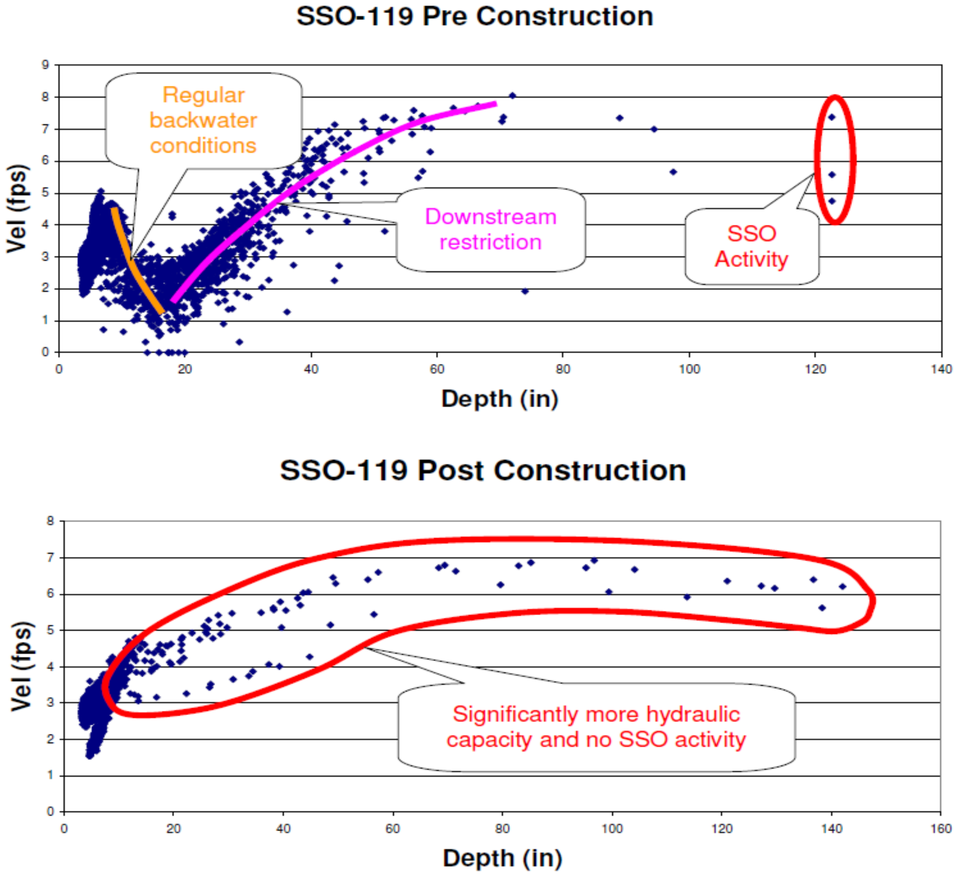


Figure 2.3.1 – Pre and Post-Construction Scattergraphs for SSO#119

2.4 Hydraulic Model Simulations

The CD requires that the hydraulic model be used in conjunction with available flow monitoring to evaluate effectiveness of the Paragraph 8 construction projects. However, as previously noted, the Paragraph 8 projects constructed in the Herring Run sewershed were completed to increase hydraulic capacity and not to reduce infiltration and/or inflow. A pre-construction hydraulic model was compared to the post-construction model. The two models were analyzed and compared for the National Resource Conservation Service (NRCS) 2-year design storm with baseline flows for both pre-construction and post-construction conditions.

A comparison of Paragraph 8 projects is shown in Table 2.4.1. It can be seen from the table that the volume of SSO's has been reduced in the sewershed.

Table 2.4.1 - Pre- and Post-Construction Hydraulic Model SSO Reductions

SSO Location	SSO Volume (million gallons)		% Reduction
	Pre-Construction	Post-Construction	
SSO 92	No Information	No Information	---
SSO 93	N/A	0	---
SSO 94	N/A	0	---
SSO 118	No Information	No Information	---
SSO 119	No Information	No Information	---
All Manholes	1.815	1.783	2%
Total:	**1.815**	**1.783**	**2%**

Note: No Information = SSO Eliminated Prior to Flowmetering Period
N/A = SSO Eliminated by Paragraph 8 Project Prior to Flowmonitoring Period and not Included in Hydraulic Model

2.5 Conclusions

The analysis of the available flow data from SSO 119 shows a significant increase in system capacity and no SSO activity after construction of SC 817. Furthermore, a comparison of pre- and post construction hydraulic model simulations show a 2-percent reduction in SSO volume for the 2-year storm throughout the sewershed. In conclusion, pre and post-construction flow data and hydraulic model simulations indicate that the Paragraph 8 construction projects in the Herring Run Sewershed have been effective in providing additional hydraulic capacity and reducing overflows. The Paragraph 8 projects alone, however, have not been sufficient and additional construction projects will be necessary as identified and recommended in Sections 5 and 7 of this report.

3.0 Flow Monitoring Program

3.1 Overall Description

To fully understand the dynamics of the sewage collection system, the City adopted a comprehensive, City-wide rainfall and flow monitoring program. The program consisted of flow meters within the City's collection system and rain gauges installed throughout the City of Baltimore and Baltimore County. The meters measured depth and velocity, from which flow was calculated at five minute intervals.

Under City of Baltimore Project 995, the comprehensive program, consisting of over 350 flow monitors for a twelve-month period was completed. The program, extending from May 9, 2006 to May 18, 2007, was designed to evaluate infiltration and inflow (I/I) at an average density of one meter for every 25,000 linear feet of pipe. Using wireless remote data collection, the program achieved an overall 97 percent data uptime, exceeding the 90 percent uptime required by the CD. Furthermore, the program achieved a low 9 percent inferred, or "qualified" data, meaning that on average the meters collected both a depth and a corresponding velocity measurement for the same time increment 91 percent of the time.

Sufficient dry and wet weather flow data was collected during the initial 12-month comprehensive program to enable the network to be reduced to approximately 100 meters (deemed long-term meters) in May 2007. These long-term meters will be used for continuous system assessment and model calibration, and have remained in service for over two years, exceeding the CD requirement of at least 18 months of flow monitoring under Paragraph 9.E.iii.b.

3.2 Metering Network Within the Herring Run Sewershed

There were 82 flow meters installed within the Herring Run Sewershed. Sixty two of the meters were installed for infiltration and inflow (I/I) evaluation; whereas, 12 long-term meters were installed for long-term assessment and hydraulic model calibration and eight supplemental meters were installed to provide additional data for model calibration. Table 3.2.1 lists the meters within the sewershed, their purpose, and operational history. Map 3.2.1 depicts the location of the meters, rain gauges, and ground water gauges within the sewershed. Figure 3.2.1 depicts a schematic of the monitoring plan for the Herring Run.

Under Project 995, the flow monitoring contractors performed independent depth and velocity measurements (field confirmations or calibrations) across the full range of depths during dry and wet weather conditions throughout the project duration, assessed monitor performance relative to these measurements, and made any necessary adjustments to the equipment to maximize the accuracy of the data with respect to actual conditions. A total of 540 field confirmations were scheduled and performed throughout the flow monitoring period – see Attachment 3.2.1 for details.

Table 3.2.1 - Herring Run Flow Meter Purpose and Operational History

Meter	Purpose	Operational Date		Meter	Purpose	Operational Date	
		Start	End			Start	End
BHR1	Calibration	5/9/06	Long Term	HR33	I/I	5/9/06	5/18/07
BHR2	Calibration	5/9/06	Long Term	HR34	I/I	5/9/06	5/18/07
BHR3	Calibration	5/9/06	Long Term	HR35	I/I	5/9/06	5/18/07
BHR4	Calibration	5/9/06	Long Term	HR36	I/I	5/9/06	5/18/07
HR01	I/I	5/9/06	5/18/07	HR37	I/I	5/9/06	5/18/07
HR02	I/I	5/9/06	5/18/07	HR38	I/I	5/9/06	5/18/07
HR02A	I/I	5/9/06	5/18/07	HR39	I/I	5/9/06	5/18/07
HR02B	I/I	5/9/06	5/18/07	HR40	I/I	5/9/06	5/18/07
HR03	I/I	5/9/06	5/18/07	HR41	I/I	5/9/06	5/18/07
HR04	I/I	5/9/06	5/18/07	HR42	I/I	5/9/06	5/18/07
HR05	I/I	5/9/06	5/18/07	HR42A	I/I	5/9/06	5/18/07
HR06	I/I	5/9/06	5/18/07	HR43	I/I	5/9/06	5/18/07
HR07A	I/I	5/9/06	5/18/07	HR44	I/I	5/9/06	5/18/07
HR07B	I/I	5/9/06	5/18/07	HR45	I/I	5/9/06	5/18/07
HR08	I/I	5/9/06	5/18/07	HR46	I/I	5/9/06	5/18/07
HR09A	I/I	5/9/06	5/18/07	HR47	I/I	5/9/06	5/18/07
HR09B	I/I	5/9/06	5/18/07	HR48	I/I	5/9/06	5/18/07
HR10	I/I	5/9/06	5/18/07	HR49	I/I	5/9/06	5/18/07
HR11	I/I	5/9/06	5/18/07	HR50	I/I	5/9/06	5/18/07
HR12	I/I	5/9/06	5/18/07	HR51	I/I	5/9/06	5/18/07
HR13	I/I	5/9/06	5/18/07	HR52	I/I	5/9/06	5/18/07
HR14	I/I	5/9/06	5/18/07	HR53	I/I	5/9/06	5/18/07
HR15	I/I	5/9/06	5/18/07	HR54	I/I	5/9/06	5/18/07
HR16	I/I	5/9/06	5/18/07	HR55	I/I	5/9/06	5/18/07
HR17	I/I	5/9/06	5/18/07	HR56	I/I	5/9/06	5/18/07
HR18	I/I	5/9/06	5/18/07	HRQD	Calibration	5/9/06	Long Term
HR19	I/I	5/9/06	5/18/07	HRQS	Calibration	5/9/06	Long Term
HR20	I/I	5/9/06	5/18/07	HRS4	Calibration	5/9/06	Long Term
HR21	I/I	5/9/06	5/18/07	PSQUA	Calibration	5/9/06	Long Term
HR22	I/I	5/9/06	5/18/07	TSHR01	Calibration	5/9/06	Long Term
HR23	I/I	5/9/06	5/18/07	TSHR02	Calibration	5/9/06	Long Term
HR24	I/I	5/9/06	5/18/07	TSHR03	Calibration	5/9/06	Long Term
HR25	I/I	5/9/06	5/18/07	TSHR04	Calibration	5/9/06	Long Term
HR26	I/I	5/9/06	5/18/07	TSHR05A	Supplemental	8/8/07	1/31/09
HR27A	I/I	5/9/06	5/18/07	TSHR05B	Supplemental	8/9/07	1/31/09
HR27B	I/I	5/9/06	5/18/07	TSHR06A	Supplemental	8/6/07	1/31/09
HR28	I/I	5/9/06	5/18/07	TSHR06B	Supplemental	8/7/07	1/31/09
HR29	I/I	5/9/06	5/18/07	TSHR07A	Supplemental	8/4/07	1/31/09
HR30	I/I	5/9/06	5/18/07	TSHR07B	Supplemental	8/5/07	1/31/09
HR31	I/I	5/9/06	5/18/07	TSHR08A	Supplemental	8/2/07	1/31/09
HR32	I/I	5/9/06	5/18/07	TSHR08B	Supplemental	8/3/07	1/31/09

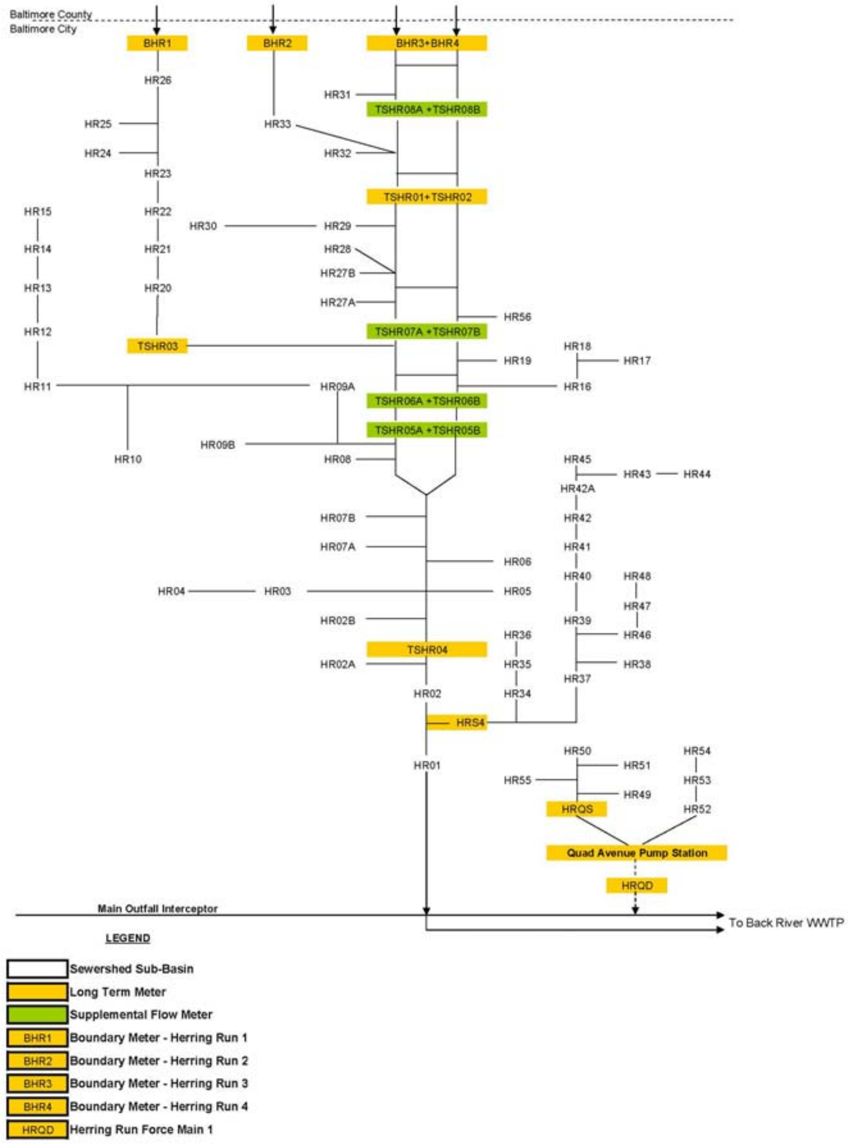


Figure 3.2.1 – Flow Meter Schematic

3.3 Rainfall Measurement

Under Project 995, the City measured the contribution from rainfall using a network of rain gauge stations with a minimum coverage of one (1) rain gauge station per ten (10) square miles supplemented by rainfall data compiled by Doppler radar utilizing a minimum resolution of one (1) pixel per four (4) square kilometers. To measure the contribution from rainfall occurring in portions of the Collection System outside Baltimore City limits, the City installed additional rain gauges in the County. Figure 3.3.1 on the following page presents the network of rain gauges in the City and County.

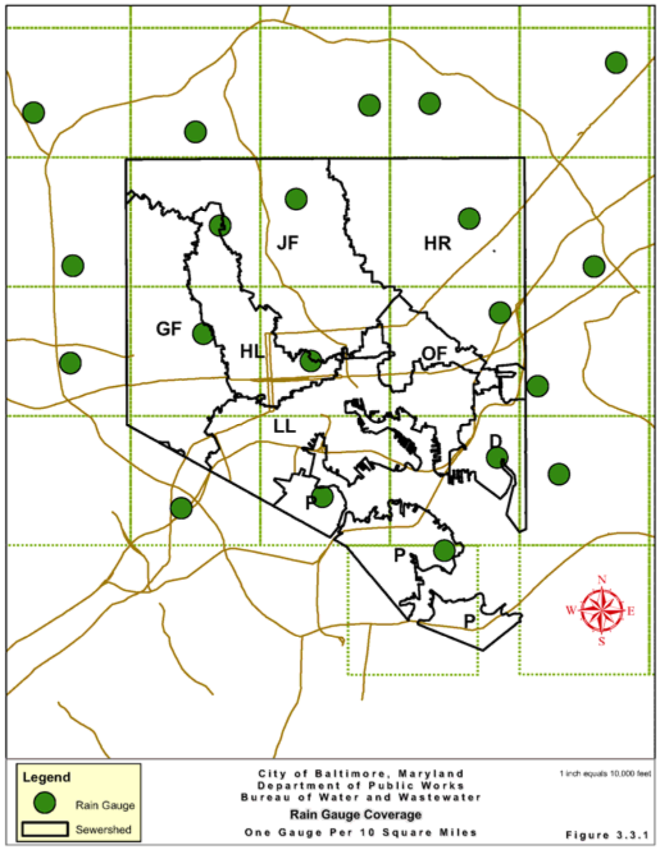


Figure 3.3.1 – Rain Gauge Network

3.4 Dopplar Radar Analysis

As required by the Consent Decree, Paragraph 9.E.iii.a, the City performed (under Project 995) Doppler Radar Rainfall Analysis in conjunction with rain gauges at a resolution of 1 gauge for every 10 square miles. The City utilized the CALAMAR software platform to process each recorded rainfall. CALAMAR uses three databases: a radar image database, a rain gauge database and a geographical database. After collecting the rain gauge network data and the radar images, CALAMAR produces a model that provides geographically accurate, integrated rainfall intensity data for any pre-defined area. The geographical area was divided into 1 square kilometer (approximately 247 acres) pixels and, for every significant rain event, Doppler radar rainfall images were generated for every pixel within the Back River and Patapsco wastewater treatment plant service areas. As shown in Table 3.4.1, a total of 39 storms were analyzed during the period between May 2006 and November 2007.

Table 3.4.1 - Storms Selected for Doppler Radar Analyis

Event Start Date	Total Rainfall (Inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)
5/11/2006	1.50	0.12	0.83
6/1/2006	2.43	0.06	0.54
6/19/2006	0.38	0.10	0.14
6/25/2006	3.63	0.19	1.27
6/26/2006	2.59	0.06	0.81
6/28/2006	0.52	0.06	0.27
7/5/2006	2.54	0.17	1.07
7/22/2006	0.93	0.10	0.60
8/7/2006	0.45	0.02	0.26
9/1/2006	2.78	0.07	0.31
9/5/2006	1.80	0.10	0.52
9/14/2006	1.65	0.04	0.18
9/28/2006	0.85	0.12	0.43
10/5/2006	1.70	0.04	0.19
10/17/2006	1.11	0.09	0.22
10/27/2006	1.99	0.05	0.28
11/7/2006	1.43	0.07	0.36
11/16/2006	1.93	0.16	0.78
11/22/2006	0.57	0.03	0.09
12/22/2006	0.90	0.03	0.12

Event Start Date	Total Rainfall (Inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)
1/1/2007	0.88	0.06	0.36
1/7/2007	0.84	0.05	0.11
3/1/2007	1.05	0.06	0.26
3/15/2007	2.10	0.08	0.19
4/4/2007	0.50	0.06	0.31
4/11/2007	0.92	0.04	0.28
4/14/2007	2.69	0.08	0.35
5/12/2007	0.49	0.04	0.46
6/3/2007	1.07	0.03	0.60
6/13/2007	0.54	0.08	0.21
7/3/2007	0.66	0.02	0.34
8/9/2007	0.86	0.08	0.43
8/20/2007	1.25	0.07	0.64
10/9/2007	0.20	0.04	0.10
10/10/2007	0.52	0.13	0.32
10/24/2007	0.88	0.04	0.21
10/25/2007	0.40	0.02	0.13
10/26/2007	4.27	0.16	0.31
11/15/2007	0.65	0.06	0.15

3.5 Data Flow Summary and Quality Assurance/Quality Control Processes

Under City of Baltimore Project 1015, the City utilized a host software support application program for remote wireless data collection of all flow meters, rain gauges and ground water gauges. The host software maintained clock synchronization with the host system's clock for all field equipment, thus insuring time interval integrity for all collected data. The flow monitoring service providers (working under Project 995) employed trained data analysts experienced in processing and analyzing flow and rainfall data from sanitary sewer systems. Various analytical tools, such as hydrographs, scattergraphs and flow balancing methods were used to verify the accuracy and prevision of the flow data. Data collection was performed remotely at least twice per week and was scheduled in a manner to allow data review by a trained data analyst within 24-hours of the data collection. The analyst assessed any maintenance or monitor performance issues and a crew was dispatched within 48 hours and the issue was resolved within 72 hours from the time the issue was identified. All measurements, adjustments and efforts undertaken during site visits were logged in an installation/maintenance log specific to that installation. Approved data was then made available to Black & Veatch through the flow metering consultant's Sliicer web site for analysis.

Once the data was downloaded from the Sliicer web site, a preliminary QA/QC review was performed. Various flow meter data components were analyzed to identify obvious discrepancies. Data components that were considered included:

i. Flow balancing - using the flow meter schematic, the gross average daily flow rates were compared to ensure that the flow totals increased at successive downstream flow meters

ii. Hydrograph analysis - hydrographs of each site were reviewed, including depth and velocity readings, to ensure that flows conformed to typical diurnal flow patterns consistent for the nature of the service area
iii. Scattergraph analysis - scattergraphs (depth versus velocity) of each site were reviewed to ensure that flows conformed to typical flow patterns or to investigate anomalies
iv. Flow comparisons - average rates for various flow components such as Base Infiltration and RDII were compared to drainage area characteristics such as length of sewer, surface drainage area, etc. to confirm that flows conformed to typical flow ranges or comparative industry numbers

3.6 Dry Weather Analysis

This sub-section provides an overall summary of the dry weather analysis. A more complete analysis is included in Attachment 3.8.1 - The Herring Run I/I Evaluation Report.

3.6.1 Base Infiltration Rates and Severity

The dry day results are shown on Table 3.6.1. As shown on this table, the base infiltration has been normalized by inch-diameter-miles (IDM). The basins (excluding basins with unfavorable hydraulic conditions and the calibration flow meter basins) with the highest base infiltration rates abut former or active stream valleys. Topographically, these areas are located near the lowest ground elevations in the sewershed. Areas of low ground elevations can experience high seasonal groundwater fluctuations, which could explain the high base infiltration in these particular basins. The basin with the highest infiltration rate (excluding basins with poor or questionable data and the calibration flow meter basins) normalized by IDM is HR07A, which is located within the Herring Run sub-sewershed. Among the basins with the highest base infiltration rates, four are located within the Upper Herring Run sub-sewershed, two are in the Chinquapin sub-sewershed, four are in the Herring Run sub-sewershed. Map 3.6.1 depicts the severity of the base infiltration, normalized by IDM. The infiltration rates were divided into five different ranges, as depicted on this map.

From a sub-sewershed basis, the Upper Herring Run sub-sewershed has the highest base infiltration rate (excluding basins with unfavorable hydraulic conditions and the calibration flow meter basins) of approximately 58,369 gpd per IDM. The Herring Run sub-sewershed has a rate 99 percent of that of Upper Herring Run sub-sewershed. The sub-sewershed with the lowest infiltration rate is Moore’s Run Low Level with a rate of approximately 5,679 gpd per IDM.

Table 3.6.1 - Dry Weather Analysis Table

Flow Meter Basin ID	Gross Drainage Area (acres)	Inch-Diam-Mile (IDM)	Net Avg. Dry Weather Rate (mgd)	Net Avg. Waste Water Flow Rate (mgd)	Net Avg. Base Infiltration (mgd)	Base Infiltration Severity (gpd/IDM)	Base Infiltration Rate (%)	Wastewater Flow Rate (gpd/lf)
TSHR04	599.54	306.88	3.40	4.49	-1.10	-3,578.76	-32.34	3.45
TSHR03	18.10	0.40	0.82	0.56	0.26	654,193.98	31.47	5.39
TSHR02	238.78	52.58	4.08	2.74	1.34	25,570.50	32.92	6.74
TSHR01	1.79	2.10	3.13	1.96	1.16	554,709.49	37.20	7.38
PSQUA	0.37	5.01	0.09	-0.42	0.13	25,728.72	138.50	8.41
HRS4	153.26	63.39	0.55	0.39	0.16	2,527.07	29.03	9.37
HRQS	408.78	86.85	0.68	0.33	0.34	3,946.30	50.72	133.98
HRQD	68.59	36.41	0.70	1.14	-0.48	-13,052.15	-67.43	26.67
HR56	31.26	9.26	0.10	0.07	0.03	3,676.41	33.61	11.13
HR55	97.89	10.88	0.08	0.04	0.04	3,770.56	53.15	5.78
HR54	190.72	56.68	0.39	0.25	0.14	2,516.53	36.58	7.18
HR53	359.35	50.64	0.51	0.35	0.16	3,163.42	31.71	12.48
HR52	381.67	76.39	2.19	1.35	0.83	10,914.17	38.12	46.78
HR51	191.49	57.43	0.48	0.22	0.26	4,507.43	53.65	6.64
HR50	115.21	29.54	0.18	0.08	0.10	3,399.12	56.03	4.43
HR49	123.61	21.47	0.13	0.04	0.09	4,067.51	69.51	2.91
HR48	199.59	42.29	0.24	0.11	0.13	3,114.49	54.91	4.27
HR47	158.26	44.46	0.19	0.08	0.11	2,492.46	59.16	2.93
HR46	184.33	55.48	0.50	0.17	0.33	5,963.81	66.52	5.16
HR45	173.23	47.39	0.36	0.16	0.20	4,230.29	55.63	5.26
HR44	121.13	33.63	0.29	0.11	0.18	5,229.01	61.35	5.02
HR43	131.92	39.79	0.05	0.03	0.02	540.19	43.80	1.15
HR42A	25.67	8.62	0.14	0.09	0.05	5,716.50	35.71	22.20
HR42	121.42	35.62	0.12	0.07	0.05	1,467.75	42.71	3.15
HR41	183.76	52.17	0.21	0.11	0.10	1,984.52	49.59	3.29
HR40	177.59	53.06	0.02	0.00	0.01	259.55	86.39	0.07
HR39	136.82	40.52	0.38	0.30	0.09	2,140.50	22.71	10.81
HR38	118.64	33.36	0.25	0.07	0.18	5,366.32	72.22	3.20
HR37	253.39	94.46	0.08	0.47	0.00	0.00	0.00	9.78
HR36	151.47	48.52	0.31	0.14	0.17	3,482.45	55.00	4.52
HR35	179.63	54.13	0.43	0.20	0.23	4,262.38	53.59	6.32
HR34	275.39	65.14	0.12	0.08	0.03	474.33	26.84	2.22
HR33	282.79	58.31	0.81	0.60	0.21	3,592.35	25.88	19.44
HR32	135.41	34.87	0.68	0.32	0.36	10,356.99	52.74	14.30
HR31	143.16	30.28	0.36	0.08	0.28	9,176.00	77.90	4.18
HR30	103.14	28.35	0.13	0.07	0.07	2,369.69	50.79	3.50
HR29	119.19	34.62	0.18	0.06	0.13	3,706.72	69.82	2.65
HR28	175.55	55.40	0.39	0.18	0.21	3,856.24	54.15	5.20
HR27B	73.42	20.93	0.28	0.21	0.07	3,261.58	24.82	15.61
HR27A	58.33	15.02	0.08	0.02	0.06	3,948.15	72.38	2.28

Represents Sites with Unfavorable Hydraulic Conditions
Represents Site Specific Values that appear to be Invalid/Irregular

Flow Meter Basin ID	Gross Drainage Area (acres)	Inch-Diam-Mile (IDM)	Net Avg. Dry Weather Rate (mgd)	Net Avg. Waste Water Flow Rate (mgd)	Net Avg. Base Infiltration (mgd)	Base Infiltration Severity (gpd/IDM)	Base Infiltration Rate (%)	Wastewater Flow Rate (gpd/lf)
HR26	207.33	52.12	0.38	0.22	0.16	3,145.90	43.20	7.02
HR25	254.65	68.02	0.44	0.18	0.26	3,791.13	58.69	4.67
HR24	215.94	60.02	0.41	0.19	0.22	3,680.06	54.09	5.21
HR23	143.01	43.08	0.09	0.07	0.02	437.46	21.02	2.64
HR22	229.89	52.87	0.52	0.17	0.35	6,596.83	67.64	4.49
HR21	136.66	30.36	0.09	0.08	0.01	306.65	10.80	3.55
HR20	184.77	37.65	0.71	0.47	0.24	6,350.34	33.91	17.90
HR19	130.44	32.66	0.38	0.12	0.26	7,972.56	68.46	6.04
HR18	104.64	29.03	0.17	0.07	0.09	3,186.22	55.85	3.92
HR17	146.87	38.62	0.36	0.12	0.24	6,264.34	67.24	4.80
HR16	130.42	44.08	0.05	0.02	0.03	594.18	52.38	0.95
HR15	164.85	53.89	0.31	0.15	0.16	2,904.16	50.83	4.85
HR14	175.24	57.07	0.02	0.00	0.03	590.80	159.33	0.00
HR13	83.28	27.21	0.58	0.33	0.25	9,261.29	43.08	23.46
HR12	137.27	62.41	0.49	0.27	0.23	3,654.62	46.19	8.33
HR11	192.80	84.17	0.72	0.55	0.17	1,989.69	23.30	12.86
HR10	61.20	23.57	0.24	0.11	0.13	5,571.36	53.74	7.76
HR09B	124.06	35.75	0.10	0.03	0.07	1,957.99	70.25	2.42
HR09A	255.48	68.07	0.00	0.00	0.00	0.00	0.00	0.00
HR08	114.20	34.64	0.29	0.06	0.23	6,763.37	79.60	2.77
HR07B	67.97	19.14	0.14	0.04	0.10	5,054.74	68.71	3.49
HR07A	93.50	21.18	0.41	0.09	0.32	15,131.04	77.42	6.90
HR06	149.29	33.27	0.23	0.07	0.15	4,602.45	67.92	3.45
HR05	91.49	31.47	0.29	0.11	0.18	5,693.37	62.23	5.39
HR04	233.11	29.63	0.32	0.13	0.19	6,524.77	60.10	6.49
HR03	137.36	49.21	0.31	0.22	0.10	1,986.40	31.08	7.30
HR02B	104.32	28.67	0.30	0.15	0.14	4,984.88	48.18	8.42
HR02A	102.50	12.51	0.14	0.06	0.08	6,772.47	58.45	8.94
HR02	59.83	48.16	1.97	0.85	1.12	23,167.32	56.76	125.12
HR01	172.56	107.75	0.18	0.46	0.00	0.00	0.00	22.26
BHR4	1,838.66	19.14	3.41	1.90	1.51	79,138.22	44.42	8.46
BHR3	628.74	2.55	0.28	0.22	0.05	21,285.38	19.69	2.68
BHR2	1,535.23	22.54	2.09	0.98	1.11	49,349.76	53.23	5.38
BHR1	273.48	0.48	0.43	0.22	0.20	418,730.59	47.61	5.00

Represents Sites with Unfavorable Hydraulic Conditions
Represents Site Specific Values that appear to be Invalid/Irregular

3.6.2 Correlation with Completed Sewer CCTV and Manhole Inspections

There appears to be some correlation between the rate of base infiltration and the manhole leaks reported from the manhole inspections. For example, the Upper Herring Run sub-sewershed has the highest rate of base infiltration and has the second highest rate of manhole leaks. The Herring Run sub-sewershed has the second highest rate of base infiltration and the fourth-highest number of rate of manhole leaks. However, there appears to be a lack of correlation between the evidence of infiltration from the CCTV inspections and the rate of base infiltration. In general, significant based infiltration was not observed in many of the CCTV inspections.

Based on sewer CCTV inspections completed under Sanitary Contracts 856 and 871 (reference Section 1.4), a strong correlation appears to exist between observed and calculated base infiltration in the Herring Run sub-sewershed. Significant base infiltration was observed throughout most of the Herring Run Interceptor located in the Herring Run sub-sewershed. The sewer segments with the highest levels of infiltration were located under or adjacent to the Herring Run stream. As noted in Section 1.4, portions of the interceptor will be rehabilitated or replaced under Sanitary Contracts 856 and 871.

3.6.3 Influence of Groundwater Table on Infiltration Rates

To assess the impact of the groundwater table on infiltration rates, a comparison of infiltration rates from summer vs. winter was completed, and it is apparent that the winter infiltration rates are higher than the summer rates, indicating that as the ground water table gets higher in elevation, the infiltration rates increase. The groundwater table level is affected by climatic changes. The groundwater table will thus fluctuate both with the seasons and from year to year. During winter, the ground water table is higher and the soils are saturated with water. In the summer, conditions reverse as the ground water table is lower and the soil is drier.

3.6.4 Base Infiltration from Baltimore County

The base infiltration rate coming from Baltimore County is estimated from Meters BHR1, BHR2, BHR3 and BHR4. Some County-contributed flows located north of the City (HR25, HR26, and HR44) and east of the City (HR54, HR53, and HR52) were not measured; however, County-contributed flow at these locations was considered negligible. The flow data indicates that approximately 47-percent of the average daily flow from the County is base infiltration. This value is slightly lower than the average rate within the City. The average base infiltration for these meters, normalized by IDM, is approximately 568,504 gpd per IDM.

3.7 Wet Weather Analysis

This sub-section provides an overall summary of the wet weather analysis. A more complete analysis is included in Attachment 3.8.1 – The Herring Run I/I Evaluation Report.

Table 3.7.1 - Wet-Weather Analysis Table

Flow Meter ID	Net RDII Response Per Inch of Rainfall (gal/LF/in)	"Capture Coefficient" % of Rainfall Entering as Net RDII Response (%)	RDIII Ranking	Capture Coefficient Ranking
BHR1	1388.44	4.28	---	---
BHR2	40.33	1.29	---	---
BHR3	362.77	3.10	---	---
BHR4	72.55	1.91	---	---
HR01	298.53	100.00	---	---
HR02	397.18	100.00	---	---
HR02A	0.69	0.17	56	56
HR02B	6.72	4.29	38	35
HR03	4.98	3.93	46	39
HR04	4.44	1.37	50	54
HR05	4.82	3.88	47	40
HR06	4.06	2.08	51	51
HR07A	8.26	4.36	29	34
HR07B	4.47	3.03	49	48
HR08	8.15	5.63	30	25
HR09A	29.61	11.53	---	---
HR09B	8.88	3.20	30	47
HR10	18.06	15.66	9	3
HR11	10.00	8.11	24	18
HR12	5.18	4.39	34	33
HR13	13.21	8.21	18	17
HR14	4.05	2.80	52	50
HR15	4.77	3.29	48	45
HR16	18.60	13.03	7	6
HR17	8.40	5.12	28	27
HR18	6.07	3.95	40	38
HR19	5.95	3.30	42	44
HR20	41.99	21.59	1	1
HR21	20.67	11.94	4	9
HR22	6.24	3.67	39	42
HR23	2.68	1.83	54	53
HR24	13.00	7.90	19	19
HR25	7.98	4.44	31	32
HR26	3.63	1.96	53	52
HR27A	16.00	9.91	12	11
HR27B	27.24	17.93	2	2
HR28	8.98	6.50	26	23

Represents Sites with Unfavorable Hydraulic Conditions

Represents Site Specific Values that appear to be Invalid/Irregular

Flow Meter ID	Net RDII Response Per Inch of Rainfall (gal/LF/in)	"Capture Coefficient" % of Rainfall Entering as Net RDII Response (%)	RDIII Ranking	Capture Coefficient Ranking
HR29	14.87	9.53	15	14
HR30	11.14	7.32	20	20
HR31	11.07	5.32	21	26
HR32	5.93	3.62	43	43
HR33	16.63	6.61	11	22
HR34	9.94	5.01	25	28
HR35	17.23	11.06	10	10
HR36	18.17	13.38	8	5
HR37	27.95	19.24	---	---
HR38	13.85	9.15	17	15
HR39	18.61	13.56	6	4
HR40	5.99	3.73	41	41
HR41	14.17	9.00	16	16
HR42	10.45	6.99	22	21
HR42A	99.32	56.36	---	---
HR43	14.90	9.83	14	12
HR44	18.74	12.47	5	8
HR45	8.92	5.70	27	24
HR46	15.05	9.62	13	13
HR47	21.00	12.62	3	7
HR48	10.10	4.68	23	31
HR49	2.66	1.03	55	55
HR50	7.31	4.11	36	36
HR51	5.06	3.24	45	46
HR52	91.15	25.20	---	---
HR53	10.29	2.89	24	49
HR54	7.55	4.97	32	29
HR55	17.56	4.09	10	37
HR56	6.93	4.88	33	30
HRQD	210.35	88.20	---	---
HRQS	13.99	3.93	---	---
HRS4	6.55	2.86	---	---
PSQUA	700.10	5,847.38	---	---
TSHR01	3312.73	3,555.99	---	---
TSHR02	95.21	39.21	---	---
TSHR03	662.82	170.46	---	---
TSHR04	101.60	58.49	---	---

Represents Sites with Unfavorable Hydraulic Conditions
Represents Site Specific Values that appear to be Invalid/Irregular

3.7.1 Observed Peak Flows

Data from the flow metering provides the peak flows from each storm for each meter. This data is shown on the hydrographs provided in Attachment 3.8.1.

3.7.2 Rain Dependent Infiltration/Inflow (RFII) Rates and Severity

The RDII has been normalized by linear feet of pipe and inches of rainfall. These results are shown on Table 3.7.1 and on Map 3.7.1. The basin with the greatest RDII severity (excluding basins with unfavorable hydraulic conditions and the calibration flow meter basins) is HR27B located within the Upper Herring Run sub-sewershed, which has a value of approximately 27.24 gallons per linear foot per inch of rainfall. Twenty five of the 56 meter basins have a normalized RDII value greater than 10 gallons per linear foot per inch of rainfall. Of these 25 basins, six each are located within the Moore's Run and Upper Herring Run sewersheds, three each are in the Belmar and Tiffany Run sub-sewersheds, two each are in the Biddison Run, Chinquapin Run, and Herring Run Low Level sub-sewersheds and one is located in the Herring Run West Branch sub-sewershed.

On a sub-sewershed basis, the Upper Herring Run sub-sewershed has the greatest severity of RDII. Normalized by length of pipe, the overall RDII for the Upper Herring Run sub-sewershed is over 141 gallons per linear foot per inch of rainfall. Other sub-sewersheds with relatively high rates of RDII are Belmar, Biddison Run, Chinquapin Run, Herring Run, Herring Run Low Level, Moore's Run and Tiffany Run all with normalized rates over 30 gallons per linear foot per inch of rainfall. The sub-sewershed with the lowest rate of RDII is the Herring Run West Branch with a rate of approximately 16.6 gallons per linear foot per inch of rainfall.

A review of the scattergraph plots included in Attachment 3.8.1 shows evidence of possible SSOs. The scattergraphs for Meters HR07A in the Herring Run sub-sewershed and Meters HR23, HR25 and TSHR03 in the Chinquapin sub-sewershed indicate evidence of possible SSOs. The scattergraphs for Meters HR35 and HR38 in the Biddison and Moore's Run sub-sewersheds, respectively, indicate evidence of possible SSOs as does Meter HR53 in the Moore's Run Low Level sub-sewershed.

The scattergraphs were also reviewed to assess the hydraulic performance of the collection system. Meter BHR2, which records flow generated from the County, experiences surcharge conditions. The maximum recorded surcharge depth over the metering period was approximately 8.4 feet.

None of the meters installed in the **Herring Run West Branch** or **Upper Herring Run** sub-sewersheds experience surcharge conditions.

With the exception of Meter HR07A, none of the remaining nine flow meters experienced surcharge conditions in the **Herring Run** sub-sewershed.

In the **Lower Herring Run** sub-sewershed, Meter HR01 experienced surcharge conditions. The maximum recorded surcharge depth was approximately 3.2 inches. None of the remaining three flow meters experienced surcharge conditions.

Three of the eight flow meters in the **Chinquapin Run** sub-sewershed experienced overflow conditions. The remaining meters did not exhibit any overflow or surcharge conditions.

None of the flow meters located in the **Tiffany Run** sub-sewershed experienced overflow or surcharge conditions. Similarly, none of the meters located in the **Lower Moore's Run** or **Belmar** or **Quad Avenue** sub-sewersheds experienced overflow or surcharge conditions.

As noted previously, Meter HR38, located in the **Moore's Run** sub-sewershed experienced surcharge conditions. Meter HR45 experienced surcharge conditions with a maximum surcharge depth of approximately 10 feet. The remaining seven meters did not exhibit any overflow or surcharge conditions.

One of the three meters in the **Biddison Run** sub-sewershed experienced overflow conditions. There were no other overflow or surcharge conditions experienced by the remaining flow meters.

One of the two meters in the **Moore's Run Low Level** sub-sewershed experienced overflow conditions. There were no other overflow or surcharge conditions experienced by the other flow meter.

None of the meters located in the **Herring Run Low Level** sub-sewershed experienced overflow or surcharge conditions.

3.7.3 Correlation with Completed CCTV and Manhole Inspections

Sewer CCTV and manhole inspections are ideally performed during seasonally high groundwater dry weather conditions so that wet-weather hydraulic flows do not adversely affect inspection conditions. Most of the inspection activities performed for this plan were completed during dry weather conditions. Therefore, there is no available inspection data to correlate to the wet-weather analysis results.

3.7.4 RDII From Baltimore County

There are four meters in the Herring Falls Sewershed that measure flow coming from Baltimore County. These meters are BHR1, BHR2, BHR3 and BHR4. Some County-contributed flows located north of the City (HR25, HR26, and HR44) and east of the City (HR54, HR53, and HR52) that were not measured. County-contributed flow at these locations was considered negligible. The flow basin with the highest RDII from the County is BHR1 with a normalized value of approximately 1,388 gallons per linear foot per inch of rainfall. The other three flow basins have values that range from 363 to 40 gallons per linear foot per inch of rainfall.

3.7.5 Smoke Testing Recommendations

Flow monitoring data and CCTV inspection results indicated that significant inflow sources may exist in the following basins, which were recommended for follow-up smoke testing:

HR09A	HR10	HR11
HR13	HR16	HR20
HR21	HR24	HR27A
HR27B	HR29	HR30
HR31	HR33	HR35
HR36	HR37	HR38
HR39	HR41	HR42
HR42A	HR43	HR44
HR46	HR47	HR48
HR52	HR55	

Reference Section 4.4 for smoke testing results and analysis.

3.8 Herring Run Sewershed Infiltration and Inflow Evaluation Report

Attachment 3.8.1 contains the Herring Run I/I Evaluation Report prepared by the Herring Run Sewershed Consultant. The report contains site reports, scattergraphs, hydrographs, and Q to I scatterplots for every flow monitoring location.

4.0 Sewer System Evaluation Study

4.1 Overview

The sewer system evaluation study (SSES) is defined as the inspection and condition assessment of the wastewater collection system. The inspection regime included:

i. CCTV inspection of all sewers (with the exception noted in Item ii) that were 8 inches in diameter and larger
ii. Sonar/CCTV inspection of the Upper and Lower Herring Run Siphons
iii. Sonar and acoustic inspection of the Quad Avenue Force Main
iv. Visual inspection of all manholes and other wastewater collection system appurtenances (e.g. junction chambers, siphon chambers, etc.)
v. Smoke testing
vi. Dyed flooding tests and dyed water tests

The completed inspection program included 1,200,000lf of CCTV inspections and 6,689 manhole inspections.

Based on a review of the inspection data, a rehabilitation and corrective action plan was developed to address critical defects.

4.2 Manhole Inspections

Manhole inspections were completed to identify manhole defects and determine the defect severity. The inspections began in February 2007 and were substantially completed in March 2009. Manholes were inspected as required by the CD in accordance with general guidelines outlined in the Environmental Protection Agency's SSES Handbook, the American Society of Civil Engineers (ASCE) Manhole Inspection and Rehabilitation Manual 92, and the newly defined requirements of the National Association of Sewer Service Companies (NASSCO) Manhole Assessment and Certification Program (MACP). In order to standardize all manhole inspections throughout the collection system, the City implemented the use of the Manhole Inspection Application Software (MIAS) developed for the City by Rummel, Klepper & Kahl, LLP. For the safety of the crews, a remote infrared manhole inspection camera was utilized to inspect and view defect images and observations in lieu of manned-entry to complete the majority of the inspections. Manhole condition assessment observations were recorded and documented in a manner consistent with MACP guidance. Manholes that could not be located or opened for inspection were documented. Inspection of these manholes will be attempted again during the Herring Run re-inspection program (reference Section 7.5.2). These structures will be inspected and incorporated into the City's overall rehabilitation plan.

The following is a brief description of the process involved in the collection of manhole inspection data for the Herring Run Sewershed. The following descriptions are not intended to cover all aspects of the work performed, rather to provide a general understanding of the data collection and review process.

- A manhole inspection crew consisting of 2 inspectors used a 1" = 100' scale GIS map to identify manholes to be inspected. This map contained information such as street names, manhole location and ID, flow direction and connectivity of the system with all other upstream and downstream manholes.

- The crew selected a manhole from the database list of manholes and went to the location where the manhole was shown on the GIS map and performed a visual search in an effort to locate the manhole or structure for inspection. If found, the manhole location was visually compared with the location indicated on the GIS map. Any discrepancies between the two locations were noted on the map.

- If a manhole structure was not found after field investigation or could not be opened, it was noted as “Cannot Locate (CNL)” or “Cannot Open (CNO)” in the MIAS database and forwarded to the City’s Wastewater Maintenance Division for locating and opening. Once the manhole was made accessible, the inspection team was notified and the site revisited and the inspection completed.

- Once a manhole was located and opened, the MIAS survey was completed. The format of the MIAS inspection form prompted the inspector to begin their inspection by recording features such as the structure’s location and then features and defects were recorded starting at the top of the manhole structure and working down to the invert. These entries included frame/cover type, condition, and materials of construction for the chimney, corbel, barrel, bench and channel and their current condition and evidence of I/I.

- Photographs were obtained and entered into the system for location views and top down views of the manhole; photographs were also collected for the pipe connections and any significant defects when possible.

- Pipe sizes were recorded and located according to clock position with the outgoing pipe always being the 12 o’clock position. Pipe diameter and rim to invert depths were also collected and recorded in MIAS along with the condition of the pipe seals.

- All manholes are then assigned a 1-5 condition rating, with 1 being in excellent condition and 5 being in very poor condition and requiring immediate attention.

All inspected manholes were assigned a five point condition rating, which was largely based on the American Society of Civil Engineer Manual of Practice 92. A summary of the inspected manhole condition ratings is provided in Table 4.2.1.

Table 4.2.1 - Manhole Condition Summary

Overall Rating	Description	Number of Manholes (ea)	Percent of Total (%)
1	Excellent Condition	2,115	31.62
2	Good Condition	3,281	49.05
3	Fair Condition	1,141	17.06
4	Poor Condition	126	1.88
5	Immediate Action Required	26	0.39
	Total Manholes Inspected:	**6,689**	

As indicated in Table 4.2.1, approximately 98-percent, or 6,587 manholes, of the inspected manholes were in fair to excellent condition. The remaining inspected manholes were in poor condition or required immediate action. As summarized in Table 4.2.2, nearly half (49-percent) of the total observed defects were located near or in the incoming and/or outgoing sewers of a manhole. Approximately 15-percent of the total observed structural defects are located in the channel and manhole walls and approximately 14-percent of the total defects are located in the manhole chimney, frame and/or cover.

Table 4.2.2 - Manhole Defect Location Summary

Manhole Component	Number of Defects (ea)	Percent of Total (%)
Cover Defect	37	0.32
Frame Defect	136	1.19
Chimney Defect	1,203	10.51
Corbel Defect	229	2.00
Barrel Defect	260	2.27
Bench Defect	550	4.81
Channel Defect	870	7.60
Pipe Defect	2,561	22.38
Pipe Seal Defect	3,081	26.93
Steps	2,515	21.98
Total Defects:	**11,442**	**---**

Approximately 23-percent of the inspected manholes indicated the presence of base infiltration. As summarized in Table 4.2.3, approximately 95-percent of the total observed manhole base infiltration was generally located on the manhole walls (e.g. manhole corbel, chimney and barrel) and, based on review of the manhole inspections, all infiltration observations indicated wet or damp manhole surfaces. Minimal base infiltration was noted in the manholes located along the stream valleys.

Table 4.2.3 - Manhole Infiltration Location Summary

Description	Number of Manholes (ea)	Percent of Total (%)
Total Manholes Inspected	6966	---
Manhole that Leak	1629	23.39
Frame Leaks	73	3.35
Chimney Leaks	458	21.02
Corbel Leaks	781	35.84
Barrel Leaks	824	37.82
Bench Leaks	31	1.42
Channel Leaks	12	0.55

A copy of the inspection reports is provided in Attachment 4.2.1.

4.3 Sewer Cleaning and Closed Circuit Television Inspection

Closed circuit television inspections were completed to identify sewer defects, determine the defect severity and confirm sewer connectivity. The inspections began in May 2006 and were substantially completed in March 2009. As required by Paragraph 9, Item D.ii of the Consent Decree, all CCTV inspections were completed and data collected in accordance with the National Association of Sewer Service Companies' (NASSCO's) Pipeline Assessment & Certification Program (PACP). All CCTV operators, equipment and QA/QC reviewers were certified in the use of the PACP coding system. All CCTV inspection observations were recorded using Flexidata, version 6.4 developed by PipeLogix.

Whenever possible, light cleaning using a hydraulically propelled high-velocity jet or other mechanically powered equipment was completed prior to CCTV inspection. Significant restrictions, such as roots or other heavy debris required heavy cleaning using a root cutter or additional passes of the hydro-cleaning equipment for critical sewers.

Whenever possible, CCTV inspections began at the upstream manhole and proceeded downstream to minimize splashing on the camera lens. When defects and/or obstructions precluded further advance of the camera, a reverse inspection, starting from the downstream manhole, was initiated. During the inspection, the camera was temporarily stopped at all observed defects and service connections to accurately code the observation and provide a clear image. For large diameter sewer inspections where temporary flow bypass could not effectively reduce the water level, a combination CCTV/sonar inspection was conducted (reference Section 4.7).

4.3.1 Structural/Operational Defects and Ratings

The PACP coding system requires the assignment of a specific code for each structural and O&M type defect identified within a pipe segment. The software automatically assigns a PACP rating code to each defect when entered. These grades are assigned based on the potential for further deterioration or possible failure of the pipe.

The PACP grading system obtained from NASSCO's "Pipeline Assessment and Certification Program" reference manual utilized for this project grades the defects as follows:

Grade	Description	Time to Failure
5	Immediate Attention Required	Pipe has failed or will within 5 yeas
4	Poor	Pipe will probably fail within 5 to 10 years
3	Fair	Pipe may fail in 10 to 20 years
2	Good	Pipe unlikely to fail for at least 20 years
1	Excellent	Failure unlikely in the forseable future

The structural pipe rating and other pipe characteristics (reference Section 7) are used to assign a condition and criticality rating to the sewer. Corrective action recommendations are prioritized based on the condition and criticality rating.

In general, the wastewater collection system serving the Herring Run Sewershed is in fair condition. As indicated in Table 4.3.1, cracks in the sewer pipe wall, which are considered minor structural defects, were the most common structural defect observed in the CCTV inspections. The most common operational defect was root intrusion.

As summarized in Table 4.3.2, approximately 70-percent of the inspected sewers have a structural grade of 3 or less. Table 4.3.3 indicates that approximately 54-percent of the inspected sewers have an O&M grade of 3 or less, indicating that approximately half of the collection system requires some type of maintenance activity. A copy of the Flexidata database used to record all CCTV inspection information is provided in Attachment 4.3.1.

Table 4.3.1 - CCTV Defect Observation Summary

Inspection Defects		Pipe Diameter (inches)					Total	Percent of total
Family	Group Type	8-12 (ea)	14-18 (ea)	20-33 (ea)	36-56 (ea)	>60 (ea)	(ea)	(%)
Structural	Crack	16777	291	193	2	0	17263	23.65
Structural	Fracture	8315	219	87	0	0	8621	11.81
Structural	Defective Joint	5621	30	2	0	0	5653	7.75
Structural	Encrustation/Scaling	4334	138	130	5	0	4607	6.31
Structural	Broken Pipe	1854	29	10	0	0	1893	2.59
Structural	Deformation	68	3	8	0	0	79	0.11
Structural	Collapse	44	0	0	0	0	44	0.06
O&M	Roots	17884	132	68	0	0	18084	24.78
O&M	Infiltration	1244	114	527	21	0	1906	2.61
O&M	Grease	1682	20	15	0	0	1717	2.35
O&M	Settled Deposits	1081	29	18	3	0	1131	1.55
O&M	Obstruction	667	26	30	0	0	723	0.99
Construction	Defective Tap	4839	19	15	12	0	4885	6.69
Construction	Line Deviations	61	1	5	6	0	73	0.10
Miscellaneous	Water Level >20%	3355	136	104	1	0	3596	4.93
Miscellaneous	Surbey Abandoned	2467	60	19	6	0	2552	3.50
Miscellaneous	Camera Underwater	143	12	4	0	0	159	0.22

Table 4.3.2 - Sewer Structural Pipe Rating Summary

Rating	Description	Sewer Segments (ea)	% of Total (%)
5	Defects that Required Immediate Attention	610	12.81
4	Poor - Severe Defects that will Become grade 5 in the Near Future	808	16.97
3	Fair - Moderate Defects that will Continue to Deteriorate	932	19.57
2	Good - Minor Defects that have not Started to Deteriorate	1,825	38.32
1	Excellent - No Defects or Minor Defects Present	587	12.33
	Total:	**4,762**	---

Table 4.3.3 - Sewer O&M Pipe Rating Summary

Rating	Description	Sewer Segments (ea)	% of Total (%)
5	Defects that Required Immediate Attention	897	18.84
4	Poor - Severe Defects that will Become grade 5 in the Near Future	1,252	26.29
3	Fair - Moderate Defects that will Continue to Deteriorate	1,191	25.01
2	Good - Minor Defects that have not Started to Deteriorate	975	20.47
1	Excellent - No Defects or Minor Defects Present	447	9.39
	Total:	**4,762**	

4.4 Smoke Testing

Smoke testing was performed to identify possible I/.I sources. During the summers of 2007 and 2008 approximately 450,000 lf of sewer was smoke tested to identify possible inflow or RDII sources such as illegal or illicit stormwater connections into the sanitary sewer collection system. Figure 4.4.1 indicates the location of the selected flow meter basins.

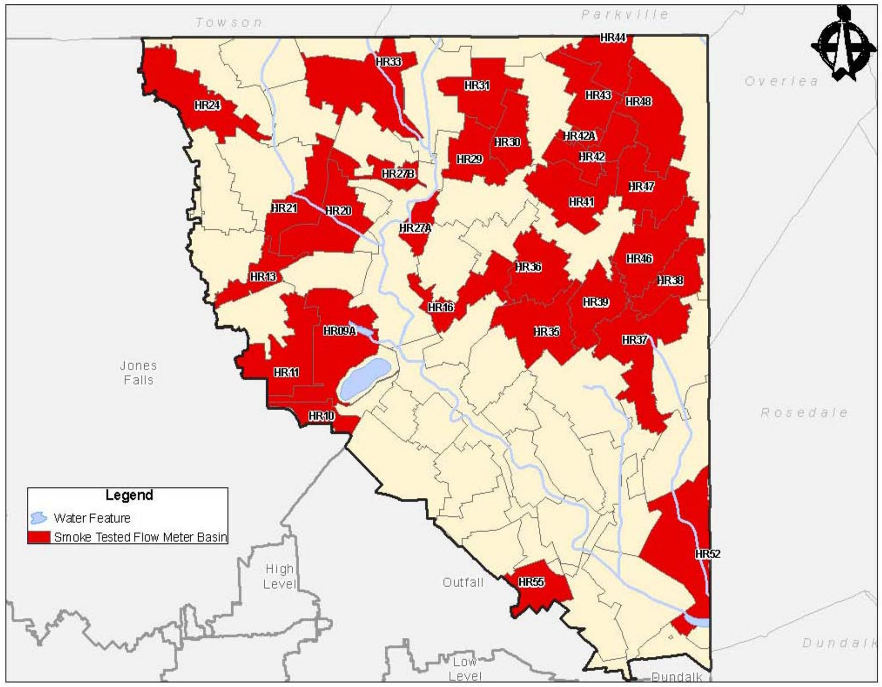


Figure 4.4.1 – Smoke Test Locations

The smoke testing was performed when the groundwater table was low and with sufficient time having elapsed from any prior rain events. Smoke testing was not performed until a minimum of 24-hours had passed from a significant wet-weather event so that the soils were sufficiently dry to allow smoke detection. Prior to initiating the smoke testing, an extensive list of property owners, hospitals, schools, local civic and community leaders, community associations, council members, and police and fire officials were notified. This process included advanced monthly notifications and the distribution of detailed smoke testing door hanger notifications extending two blocks outside the test areas at least three days prior to conducting the tests. When smoke testing was initiated and temporarily halted due to rain or other operational issues, the notification process was completed again. In most cases smoke testing was conducted using a single blower setup technique. Theatrical smoke was introduced at the blower location and pushed through sections of the pipe. The maximum sewer length tested was limited to 1,000 linear feet and smoke was introduced for a minimum of five (5) minutes before recording any observation. Field crews were responsible for determining that adequate smoke coverage was obtained by observing smoke concentrations and smoke travel using house plumbing vents along the setup as visual indicators. Smoke was continually introduced into the test setup until adequate smoke coverage was obtained in the test area. Due to financial and practical constraints, smoke testing was not performed on 15-inch diameter and larger sewers and all sewers located on property owned by the Baltimore City Department of Recreation and Parks.

Suspect inflow or RDII sources such as driveway drains, stairwell drains, window well drains, patio and area drains and downspouts piped underground or foundation drains were noted. Significant potential sources of “clear water” connections (such as storm drain or catch basin connections) were noted and were recommended for follow-up dyed-water testing to determine if actual cross connections existed. Care was taken to inspect the property around all buildings for sources of smoke.

A summary of the smoke test defect observations is provided in Table 4.4.1.

Table 4.4.1 - Smoke Testing Defect Summary

Sector	Total Defects	Percent of Total (%)
Public	511	22.80
Private	1,730	77.20
Total	**2,241**	---
Source Type	**Total Observaions**	**Percent of Total (%)**
Service Lateral	237	10.57
Window Well Drain	5	0.22
Downspout	49	2.19
Catch Basin	94	4.19
Sewer Manhole	298	13.29
Main Sewer	55	2.45
Transition joint	7	0.31
Stairwell Drain	3	0.13
Downspout Connection	32	1.43
Storm Ditch	15	0.67
Cleanout	1,362	60.75
Driveway Drain	4	0.18
Area Drain	19	0.85
Foundation Drain	8	0.36
Storm Manhole	11	0.49
Others	43	1.92
Total	**2,242**	---

A copy of the smoke test inspection reports is provided in Attachment 4.4.1.

4.5 Dyed-Water Testing

Dyed-water flooding tests where performed to confirm I/I sources. The location of each dye test was determined based on positive smoke test results. The following stormwater collection features were identified for supplemental dyed-water testing:

i. Stormwater inlets with a positive smoke test observation that were located in the public right-of-way. Based on information obtained from the respective smoke test report and associated digital photographs, the dissipating smoke density was quantified to prioritize dye floods at the locations where the existence of an illegal or illicit connection was considered most probable.
ii. Other stormwater collection features (e.g. downspouts, yard inlets, etc.) at large commercial/residential buildings such as office buildings and apartment complexes.

Dye flood tests were performed at stormwater inlets located in the public right of way with suspected direct connections to the wastewater collection system. As shown in Figure 4.5.1, dye flood tests were performed by plugging the suspected storm drain and partially filling it with dyed water. A CCTV camera inspecting the sanitary sewer observed and located defects permitting dyed stormwater and/or sources of infiltration into the sanitary sewer.

A minimum of six inches of standing water (as measured from Location A in Figure 4.5.1) was required to complete each test. This hydraulic condition was maintained for a minimum of 15 minutes. If dyed water was not detected in the sewer after 15 minutes, the test was abandoned and the negative test result was noted in the dye flood database.

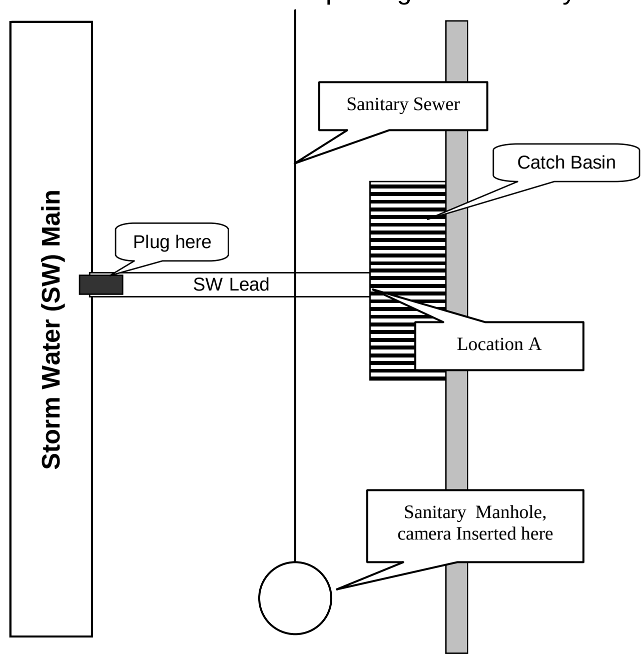


Figure 4.5.1 – Dye Flood Configuration

As shown in Table 4.5.1, there are a significant number of positive smoke test results at roof downspouts and various storm drain inlets that are located on private property Dye tests at these locations should be considered to confirm and/or address private property infiltration and inflow.

Table 4.5.1 - Dyed-Water Testing Defect Summary

Sector	Total Defects	Percent of Total (%)
Public	58	100
Private	0	0
Total	**58**	---
Source Type	**Total Observaions**	**Percent of Total (%)**
Downspout	7	12.07
Catch Basin	48	82.76
Cleanout	1	1.72
Area Drain	2	3.45
Total	**58**	---

Dye tests confirmed two stormwater locations that were directly connected to the wastewater collection system; however, the combined drainage areas were relatively small. In general, none of the 48 dye flood tests performed on various stormwater inlets confirmed a direct connection to the wastewater collection system. However, 29 of the tests confirmed stormwater exfiltration from the storm drain entering the sanitary sewer as infiltration through various sewer defects such as cracked/broken house laterals, sewer main fractures/holes and under manhole frame and covers.

A copy of the dye flood inspection reports is provided in Attachment 4.5.1.

4.6 Emergency Repairs/Rehabilitation

In accordance with Paragraph 9 Item C.iii of the Consent Decree, all significant system deficiencies observed during field inspections or when reviewing the field data were reported to the City. Figure 4.6.1 indicates the location of reported observed significant deficiencies.

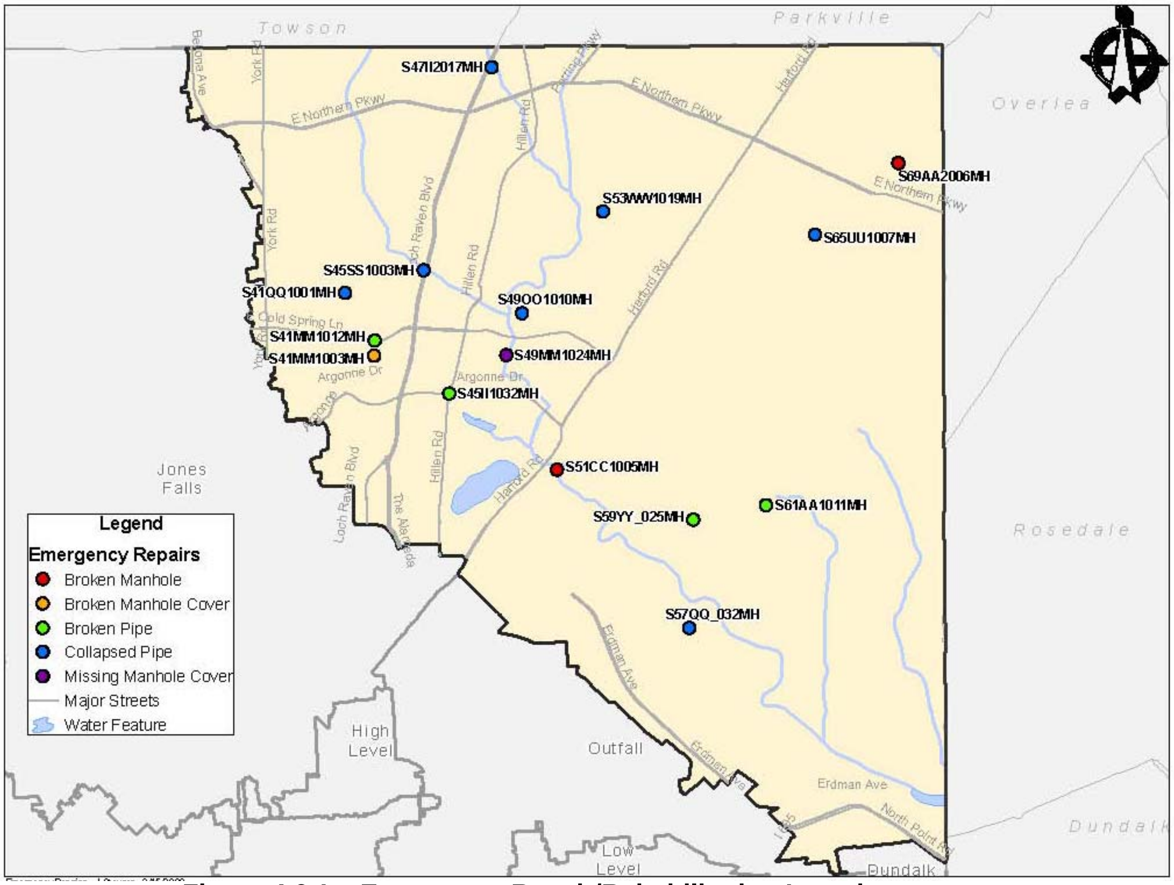


Figure 4.6.1 – Emergency Repair/Rehabilitation Locations

4.7 Quad Avenue Force Main Inspection

The Quad Avenue Pumping Station Force Main is a 36-inch diameter pre-stressed concrete cylinder pipe measuring approximately 2,180 feet in length. The force main, constructed in the mid 1970s, conveys wastewater from the Quad Avenue Pumping Station to the Outfall Relief Interceptor. In accordance with Paragraph 9, Item D.i.a of the Consent Decree, a condition assessment of the force main was completed. In December 2008, a sonar/CCTV and acoustic inspection was performed on the force main. The sonar/CCTV inspection was performed to identify areas of hydrogen sulfide corrosion and/or deposition and to locate any severe structural defects such as holes in the pipe wall. The acoustic inspection was performed to locate joint leakage and/or air pockets.

Due to access limitations, the sonar/CCTV inspection began at the downstream discharge transition manhole and progressed toward the pumping station. Approximately 1,180 lf of sonar/CCTV inspection was completed before the inspection was abandoned due to force main joint alignment offsets. The acoustic inspection began at the force main header pipe in the pumping station and traveled the entire force main length to the downstream transition manhole. The inspections did not identify any significant structural or operational deficiencies along the entire force main alignment. A copy of the Quad Avenue Force Main Assessment Report is provided in Attachment 4.7.1.

4.8 Quality Assurance/Quality Control Protocols

All field inspection work and QA/QC reviews were completed as described in the following sections. Copies of the various field work and QA/QC protocols are provided in Attachments 4.8.1 through 4.8.4.

4.8.1 Manhole Inspection Protocols

All manhole inspections were performed using proprietary data management software, known as Manhole Inspection Application Software (MIAS) provided by the City.

General information such as manhole location and connectivity was visually compared with data recorded in the City's geographic information system. Discrepancies between the two data sets were noted by the field crew on field inspection maps, which were provided with each electronic data submission. Specific condition assessment data, such as pipe depth, manhole structure material and structural and operational defects were recorded in the MIAS database by the inspector. All observed defects were photographed and cataloged in the MIAS database.

A three-level QA/QC review process was completed for each manhole inspection. A manhole inspection was not accepted until all QA/QC reviews were completed and passed. A description of each review level is provided below:

i. Level 1 – This review was intended to provide an initial check that all required data was provided and that the data conformed with the project specifications.
ii. Level 2 – This review provided a comprehensive check that all recorded data was accurate and that all provided information conformed with the project specifications. Connectivity information recorded in the manhole inspection was compared with the geographic information system. .
iii. Level 3 – This review confirmed that all Level 2 review comments are correct before additional field activities were performed. Miscellaneous outstanding Level 2 review comments were addressed by the Level 3 reviewer.

Each QA/QC review level was performed by different individuals. Manholes that did not pass a QA/QC review were reassigned to a field crew for correction. The manhole re-inspections were reviewed by the same QA/QC process as described above.

4.8.2 Sewer CCTV Inspection Protocols

All sewer CCTV inspections were reviewed for picture and sound quality and PACP coding conformance. Failed inspections were reassigned to a field crew for correction.

For selected sewer segments, the CCTV inspection could not be performed due to various field conditions (e.g. hydraulic conditions, camera underwater, root intrusion, debris deposition, etc.). Video inspections and other available data such as MIAS records and GIS data were reviewed to confirm abandoned inspection explanations. Unacceptable inspection abandonments were communicated to the field crews for re-inspection. The CCTV re-inspections were reviewed by the same QA/QC process as described above.

4.8.3 Sonar/CCTV Inspection Protocol

All sonar/CCTV inspection footage was reviewed for picture and sound quality and data completeness. Where CCTV inspection videos were provided, all footage was reviewed as described in Section 4.8.2.

4.8.4 Smoke Testing Protocol

All smoke tests were reviewed for accuracy and completeness. Review comments were forwarded to the field crew for corrections. All data was reviewed to identify significant potential I/I sources such as storm drain inlets and roof leaders. Based on the review, dye flood tests were identified and completed.

4.8.5 Dye-Water Testing

All dye flood tests were reviewed for accuracy and completeness. In some instances, a second test was performed to confirm a direct stormwater connection to the wastewater collection system. All direct connections identified by the dye flood tests were promptly reported to the City.

5.0 Hydraulic Modeling

As stated in Paragraph 12.A of the Consent Decree (CD), a hydraulic model was developed for the portion of the Herring Run sewershed within the City to assess the capacity of the collection system and to identify the measures necessary to address capacity limitations as required by Paragraph 9.F. The model must be capable of evaluating the impact of I/I rehabilitation projects, proposed system modifications, upgrades, and expansions to the transmission capacity and performance of the collection system. Per Paragraph 12.B of the CD, the model prepared is capable of predicting:

- a The volume of wastewater flow in the force mains and major gravity lines
- b Hydraulic pressure or hydraulic grade line of wastewater at any point in force mains and the major gravity lines
- c Flow capacity of each of the pumping stations in the collection system
- d Flow capacity of each pumping station with its back-up pump out of service
- e Peak flows for each pumping station during storm events of a magnitude of up to 20 years
- f Likelihood and location of overflows under high flow conditions, including pumping station service areas where the pumping station's back-up pump is out-of-service, and considering available wet well capacity, off-line storage capacity, and normal in-line storage capacity.

The model is also:

- a Configured based on representative, accurate, and verified system attribute data (i.e., pipe sizes and invert elevations, manhole rim elevations, etc.)
- b Calibrated using spatially and temporally representative rainfall data and flow data obtained during the rainfall and flow monitoring
- c Verified using spatially and temporally representative rainfall data and flow data; that data shall be independent of the data used to calibrate the model.

The model has been calibrated per Paragraph 12.E.ii and the Model Calibration Report is included in Attachment 5.2.1, as stipulated in Paragraph 12.E of the Consent Decree.

5.1 Model Network

The modeling software selected for the City of Baltimore Collection System Evaluation and Sewershed Plan is InfoWorks CS, by Wallingford Software, Limited.

The modeled network includes all force mains, major gravity lines, and pumping stations and their respective related appurtenances. The model also includes all manholes, junctions, and structures along model sewer lines, and all control structures (e.g. weirs and sluice gates) existing in the system.

The City's geographic information system (GIS) data was used to construct the model. The pipe size, invert elevation and manhole rim elevations were compared with several data set sources to enhance the quality of data and populate missing GIS information. The sources used for this purpose included record drawings, the Herring Run Hydraulic Model, which was developed by George, Miles & Buhr, LLC (GMB) in 1997, manhole inspection data, sewer closed circuit television inspection information and manhole survey data. The hydraulic model was checked within InfoWorks for errors, connectivity issues and other discrepancies.

The manhole inspection and CCTV information was utilized from project field survey efforts, along with City engineering documents, to make editing changes to the City's wastewater GIS. Manhole inspections have been completed for the majority of the approximate 7,247 manholes in the Herring Run sewershed. Data from the manhole inspections have been used to supplement, verify or correct data from the GIS and record drawings.

Record drawings for the Herring Run sewershed have been obtained from the City. Information from these drawings has been transferred into the GIS for the Herring Run system.

Based on an analysis of the field inspection data, Black & Veatch determined that inherent measurement errors associated with general field measurement activities could result in discrepancy of the sewer invert depth measurements. Black & Veatch concluded that the invert elevations recorded in the record drawings provided more accurate data. It was determined that the measurement discrepancy effects on the model results would be insignificant for 10-inch diameter and smaller sewers. Therefore, sewer invert depth measurements from the manhole inspections were used for model sewers 10-inch diameter and smaller. Invert elevations for model sewers larger than 10-inch diameter were based on the record drawings. Manhole rim elevations were taken from available GPS surveys, or from the available ground elevation model developed from XYZ mass points.

The hydraulic model network was verified using InfoWorks. Upstream and downstream checks were made to verify connectivity. Long view sections were also viewed to verify vertical correctness and any discrepancies were corrected by comparing to field and record drawing information.

The InfoWorks CS model for the Herring Run sewershed incorporates the hydrologic characteristics of the sewershed. The model utilizes the SWMM surface runoff routine within InfoWorks, which requires that wet weather flow input to the sanitary sewer system be represented differently. The SWMM surface runoff routine is used as a surrogate rainfall-dependent infiltration and inflow (RDII) simulator, meaning that although the parameters used in the runoff routines are adjusted to match the observed inflow, those parameters do not have physical significance. Hence, for wet weather flow simulation in separate sanitary sewers, the surface runoff routine of SWMM is being applied to empirically develop RDII flows in the InfoWorks model. This procedure has the advantage of allowing inflow simulation as a function of any rainfall depth and distribution, within the framework of the model rather than outside of it.

The Herring Run sewershed has been divided into sewershed service areas (SSAs). These SSAs have been incorporated into the InfoWorks model as sub-catchments. Sub-catchments have been delineated using the following guidelines:

- Sub-basin areas should be roughly 10-40 acres in size, with an average of approximately 20 acres with the exception of catchments at upstream boundaries, which may be larger.
- Sub-catchment boundaries should generally be drawn at hydraulic control points such as:
    - Flow diversion chambers
    - Pumping stations
    - Any constructed overflow point
    - Significant tributary junctions
    - Flow monitor locations

- Large parcels of land such as parks, golf courses and freeways that are not connected to the collection system should be excluded from the sub-catchments for the purposes of collection system modeling
- Sub-catchment delineations should not cross over combined or sanitary pipes: they should always end at a manhole

For each sub-catchment, a load point node is identified for the assignment of dry and wet weather flows into the hydraulic model network. Model load points were assigned to best represent the affects of flows entering the system.

There are several sources of data used in the development of dry-weather flows in the InfoWorks model. These sources include:

- Analyses of the rainfall/flow monitoring data using the Sliicer.com software
- The City's database of water consumption records for each SSA
- Population estimates for each flow monitoring basin obtained through GIS intersection with the U.S. Census Block data
- GIS estimates of tributary collection system to each flow monitor in inch-diameter-miles
- GIS estimates of the tributary sewershed area to each flow monitor

Several dry-weather days within a month were selected to generate typical weekday and weekend flow patterns per meter. These flow patterns were exported to a spreadsheet for post-processing. First, the groundwater infiltration (GWI) flow for the month used to generate the flow patterns was calculated and subtracted using the Stevens-Schutzbach method. In parallel, the spatially distributed population was clustered by meter. Then, dividing the weekday and weekend flow patterns, excluding the GWI component, by the corresponding weekday and weekend average base sanitary flow (BSF) values produced the weekday and weekend diurnal peaking factors per meter that were used in the hydraulic model to generate BSF for the entire monitored period. In addition, the BSF was divided by the number of people per meter to compute the wastewater production rates.

Base infiltration monthly factors were calculated and inputted into the hydraulic model as "Trade Flow" profiles. The monthly factors were calculated by selecting several dry-weather days per month for the year. GWI was calculated for each selected day using the Stevens-Schutzbach method and then averaged by month. The monthly GWI values were then normalized into monthly factors by dividing them by the average annual GWI value.

Input parameters were validated prior to incorporation in the InfoWorks model. Validation of the BSFs for residential areas has been performed by dividing BSF by the population of the monitoring basin to determine the per capita wastewater generation rate. These results were then compared to typical textbook or industry ranges of values for residential areas.

For basins which include industrial and commercial water users, the water consumption records, including the Top 100 City Water users database, were reviewed to determine average daily BSFs from these facilities and to validate the corresponding BSFs obtained through the Sliicer.com analyses. However no additional flow was needed to be entered into the model to capture unusual flow patterns.

The Sliicer.com analyses yielded average daily dry weather flow hydrographs for each monitoring basin for both weekdays and weekends. This data was used to develop hourly diurnal peaking factors for weekdays and weekends. This was done by first subtracting the GWI from the hourly values of the dry weather flow hydrographs and then dividing by the average BSF.

In the InfoWorks model, a profile in the wastewater group has been created for each monitoring basin. The wastewater profile contains weekday and weekend hourly diurnal peaking factors. In addition, a per capita wastewater generation rate must be specified in the wastewater profile. This generation rate, multiplied by the sub-catchment population, yielded the average BSF.

Analysis of the monitoring data also yielded model input for the simulation of wet-weather events. The wet-weather flow component in sanitary sewers is referred to as rainfall-dependent infiltration and inflow (RDII).

The approach to simulate wet weather flow in areas served by separate storm sewers uses the SWMM RUNOFF routines in InfoWorks CS as a synthetic storm hydrograph generator. In a sanitary system, the RDII is driven not by the impervious surface of the modeled catchment, but rather by a myriad of factors including:

- Age and condition of the system
- Construction practices at the time of installation
- Prevalence of direct (illicit) connections to the sanitary system
- Operation and maintenance of the system
- Antecedent moisture conditions (the saturation of the ground around the sewers)
- Groundwater elevation

To simulate inflow into sanitary sewer systems, suitable input parameters are selected to yield flow that matches inflows determined from flow meter measurements. The following is a description of the steps used to develop initial parameter estimates for the inflow model.

Simulating RDII using SWMM RUNOFF within InfoWorks requires the specification of catchment characteristics that result in reasonable RDII. The parameters to be specified are:

- Area: The total area of each sub-catchment (in acres) is calculated in GIS.
- R-Value (Percent Capture): The SWMM RUNOFF routines simulate wet weather from a modeled basin via impervious and pervious runoff. For sanitary sewer systems, the percent impervious is analogous to a percent capture or more appropriate an RDII “R-Value”. The R-Value represents the fraction of the rainfall that enters the sanitary system. Sliicer.com provides an estimate of the R-Value. The infiltration factors for pervious areas are adjusted such that there is no runoff (RDII) from pervious areas. The volume of RDII is proportional to the rainfall depth.
- Depression storage: Depression storage represents the volume, in inches, that must be filled prior to the occurrence of runoff. For surface runoff it represents the initial loss or “abstraction” caused by such phenomena as surface ponding, surface wetting, interception and evaporation. For the RDII modeling purposes, this parameter represents the depth of rainfall required to initiate a response in the sewer system. In this case, depression storage has been estimated using the intercept of the RDII volume vs. rainfall (Q vs. i plot in Sliicer.com) regression line.

- Width: The sub-catchment width is a key calibration parameter, one of the few that can significantly alter the hydrograph shape (timing of the peak flow rates) without impacting the volume. The width is determined when the simulated time-to-peak and magnitude match the observed peak RDII flow during several storms. This has been done by simulating the storm events using the model and adjusting the catchment width until the correct peak is obtained. Sub-catchment width is directly proportional to peak flow rate.
- Slope: For combined and stormwater (surface runoff) models, this value represents the physical slope of the ground surface. An average basin slope can be calculated using GIS. This value can be modified to help adjust the modeled peak flows and volumes during model calibration, but it is not a sensitive parameter.
- Overland Flow Routing Coefficients: Manning's roughness values can be modified to fine tune predicted hydrograph responses.

The RDII volume versus rainfall depth plot for each monitoring site has been developed using the Sliicer.com software. In addition, Sliicer.com also develops the best-fit linear regression to the data set and the corresponding equation for the regression line, as well as the R-Value. Twenty-five (reduced from the original 29) storms have been considered in the analyses.

To accurately reflect the hydraulics of the sewershed, boundary conditions had to be setup within the model. There are four primary sources of inflow into the model from Baltimore County and one outfall level condition that had to be included in the model. The boundary SSAs provided with the macro model was the source of information for the boundary SSAs in the micro model. Capture coefficient or "R" values were first estimated through Sliicer.com then fine-tuned through the calibration effort.

Boundary conditions at the Outfall Interceptor where provided by the City. Additionally, Black & Veatch assumed a free outfall condition for the Quad Avenue Pumping Station force main discharge as directed by the City.

A map of the hydraulic model network is provided in Map 5.1.1.

5.2 Model Calibration

After the model network has been developed and flows inputted, the next step of the development process was calibrating the model. This consisted of changing characteristics of the network and sub-catchments to accurately portray what was happening in the real world as documented by the flow metering.

Model calibration consisted of two steps. The first step was dry weather calibration. This was the process of modifying the network to reflect what was actually happening in the sewer system during a normal dry day. Following dry weather calibration, the second step was wet weather calibration. This was the process of adjusting sub-catchments parameters to behave as they did according to the metering.

The dry weather calibration began by incorporating spatially distributed population, wastewater production rates and diurnal factors, and GWI monthly factors into the model. General hydraulic parameters were initially set to expected values, like Manning's "n", in order for the model to run. Once the network had been initially been populated and validated, a simulation was run to get a first glimpse of the behavior of the model. Following the simulation, "Observed vs. Predicted" plots were generated at the flow monitoring sites to see how the model behaved compared to the flow meter data.

Any sites that required modification to meet flow depth, volume of flow, and velocity were adjusted to match the flow meter.

The following criteria were followed for the dry weather calibration:

- The modeled peak flow rate should be within -10 to +20 percent of the observed
- The modeled volume of flow should be within -10 to +20 percent of the observed
- The timing of the peaks should be within 1 hour

To assess the accuracy of the performance of the model compared to the observed data, the Observed Vs. Predicted plots were used. The shape and timing of the predicted hydrographs were compared to the observed and any major discrepancies were corrected by adjusting the diurnal curves. Depths and velocities were compared and the roughness factors and sediment depths (corresponding to field work investigations) were adjusted to match the observed.

The model simulations time period for the dry weather calibration was run for three weeks and the volumes of the predicted vs. observed were totaled by InfoWorks for the specified time period. All of the meters met the criteria for timing of the peak for the dry weather calibration. The total flow volume from model predication met the minimum specified lower bound of -10 percent for 75 percent of major meters (defined as flow meters with 2 mgd or more average daily flow), with 20 percent of the remaining major meters predictions falling below the specified lower bound by less than 3.6 percent. Only one meter, HR48, under-predicted the total volume by 8.9 percent below the specified lower bound. The peak flow from model prediction met the minimum specified lower bound of -10 percent for 80 percent of major meters, with the remaining 20 percent of major meters predictions falling below the specified lower bound by less than 4 percent. Most of the meters for which the modeled predicted values are outside the calibration criteria are meters for which data was missing for several days out of the selected range for comparison. Other meters with predicted values falling outside the calibration bounds appear to have invalid and/or irregular data during the period selected for comparison and calculation of the dry-weather statistics

Following completion of the dry weather calibration, wet weather calibration was initiated. Capture coefficients were developed from Sliicer.com and entered into the model's sub-catchments as "Fixed Runoff Coefficients". The first model runs were based on InfoWorks default values for basin slope and basin width and initial values of 0.015 for runoff routing values (roughness factor).

After reviewing the results and looking at all of the 25 storm events, different parameters were adjusted to predict the flow meter responses more accurately. Based off the sensitivity analysis completed for the model, adjustments were made.

The following were the guidelines followed for the wet weather calibration:

- the modeled peak flow rate should be within -10 percent and +25 percent of the observed peak rate,
- the modeled volume of flow should be within -10 percent and +20 percent of the observed,
- the modeled depth of flow in surcharged sewers should be within +18 inches and -4 inches in sewers 21 inches in diameter and larger (within +6 inches and -4 inches in sewers smaller than 21 inches in diameter) of the observed,

- the modeled depth of flow at unsurcharged critical points in the system, i.e., at SSO structures, should be within 4 inches of the observed, and
- the shape and timing of the hydrographs should be similar.

The variation of groundwater table elevation and antecedent moisture conditions during summer and winter seasons have a significant impact on the response of the sewer system to storm events. Summer storms typically are of shorter duration and higher intensity than winter events. The ground is dryer in the summer and the water table is lower than compared to winter. With the ground wetter and the water table higher, more infiltration and inflow occurs per the same rainfall amount for winter storms than for summer storms. This posed a challenge for calibrating the model to accurately predict both seasons. If the model is calibrated to only summer events, potential deficiencies in the system may not be fully captured. However, if the model was only calibrated to the winter storms, required improvements may be grossly over-predicted. A median R value was used in the model as a compromise. Using the average of the summer and winter R value introduces a safety margin by allowing a higher R during the more severe storms in the summer. Furthermore, by using this method, the calibration guidelines are generally met.

The hydraulic model of the Herring Run Sewershed has been built in accordance with the CD. The network was built from field verified GIS information and the flow inputs are based on 62 individual flow meters installed for over one year. Dry weather calibration was completed without having to use any unlikely conditions. For the wet weather calibration, the median R value was used to capture the differences between winter and summer storm events. Consequently, when simulating all of the 25 modeled storms as a whole and balancing the differences, the model behaves in a realistic fashion.

For a full description of the model calibration process, see Attachment 5.2.1, Herring Run Model Calibration Report.

5.3 Baseline Analysis and Capacity Assessment

5.3.1 Design Storms

Seven design storms have been analyzed. These design storms include a three-month storm having a duration equal to the time of concentration for the sewershed (2 hours) and the 1, 2, 5, 10, 15, and 20-year, 24 hour duration storms. The storm distribution chosen for analysis is the NOAA Atlas 14/NRCS distribution. The storm depths for the seven design storms are as follows:

- 3-Month – 1.11 inches
- 1-Year – 2.67 inches
- 2-Year – 3.23 inches
- 5-Year – 4.15 inches
- 10-Year – 4.97 inches
- 15-Year – 5.41 inches
- 20-Year – 5.82 inches

5.3.2 Definition of Deficiency

The standard for capacity adequacy will be to convey the flow in the system but to allow the system to surcharge. Regardless of the storm, capacity will be considered adequate as long as no SSO occurs through model-predicted manhole flooding.

5.3.3 Storm Simulations (All Storms)

One of the requirements of the CD is to run a Return Period Analysis (RPA) on the seven design storms. InfoWorks compares the surcharge state and any flooding based on each design storm and presents the minimum size storm required to surcharge and flood (cause an overflow) the system at manholes along with the estimated flood volume.

During dry weather flows there are no overflows in the Herring Run Sewershed. However, beginning at the 1-year storm event, sanitary sewer overflows (SSOs) start to occur at the junction of the Chinquapin Run and Upper Herring Run Interceptors followed by overflow conditions at the Chinquapin Run, Herring Run West Branch, Upper Herring Run (original and relief interceptors) and the Tiffany Run Interceptors. As the storm return periods increase, SSOs spread throughout the sewershed.

The Quad Avenue Wastewater Pumping Station was originally constructed in 1973, followed by major rehabilitation of the station in 2000. The pumping station is fitted with three identical pump and motor combinations, each capable of 7,000 gpm (10.1 mgd) at 74.5 total design head. The pumping station was modeled with two pumps online and the back-up pump offline.

The Quad Avenue Pumping Station discharges into a 36-inch diameter force main. It is important that the velocities within the force main do not become too elevated in order to prevent excessive head on the pumps and protect the system from scour effects. For capacity analysis of force mains in the Herring Run sewershed, velocities of greater than 7 feet per second are considered excessive. The modeling shows that the velocities remain below 7 feet per second during all design storm simulations.

See Maps 5.3.3A through 5.3.3E which depict the SSO locations for all seven design storm simulations.

5.3.4 Identification of Hydraulic Deficiencies (All Storms)

One of the requirements of the CD is to identify and map all components of the wastewater collection system that restrict flow of wastewater through the collection system and that cause or contribute, or are likely to cause or contribute, to overflows from the collection system. See Attachment 5.3.1 – Baseline Analysis and Capacity Assessment Report - for maps and descriptions for the locations of hydraulic restrictions

Most of the pipe capacity deficiencies are due to excessive inflow/infiltration into the system. However, there are locations where hydraulic restrictions due to sharp bends in the pipes, mis-matched sewer inverts, and negative slopes are the primary causes of the overflow.

5.4 Alternative Analysis (2-Year and Larger Storms)

In designing improvements, emphasis was placed on inflow and infiltration (I/I) removal from upstream locations of the identified SSO locations. From the technical program guidelines provided by the City, a comprehensive I/I removal program (CIPP lining of all public and private sewers and manhole rehabilitation/replacement) it was estimated that up to 80 percent of RDII and dry weather infiltration can be removed from the system. The guidance was proposed to only rehabilitate the public side of the collection system, therefore the model was modified to only account for a 40 percent reduction in RDII and dry weather infiltration in the locations selected for I/I reduction. Following I/I removal, the next step to minimize SSOs was upsizing pipes or adding relief sewers, adding storage, pump station upgrades and sewer pressurization. No consideration was taken for any I/I removal or other changes in flows from Baltimore County. The County is in the beginning phases of their Consent Decree with the Environmental Protection Agency (EPA), which will not be completed for several years after the Herring Run Sewershed Study is scheduled to be completed. However, any I/I reduction the County may achieve introduces additional margin of safety for the recommended improvements. The I/I reduction achieved by the County may also reduce or eliminate some of the recommended improvements.

Some of the hydraulic recommendations noted below include sealing manholes to prevent SSOs at lower-elevation locations. However, sealing a surcharging manhole will create a low-pressure condition in the sewer and the contiguous segments. The structural condition of all inspected sewers and manholes and any significant corrective action has been assessed (reference Section 7.2.2); however, the corrective action costs are not included with the hydraulic recommendation cost estimate. All recommended sewer and manhole structural corrective actions for the sewers and contiguous segments where manhole sealing is recommended must be completed prior to sealing the manhole.

For a complete description of the proposed projects to eliminate all sanitary sewer overflows for the required design storms and a break down of the individual project costs, please see Attachment 5.4.1, Herring Run Alternative Analysis Report.

2-YEAR IMPROVEMENTS

See Map 5.4.1, Herring Run Alternative Analysis (2-Year Storm) for a map depicting the location and extents for each of the following projects.

Chinquapin Run

When the Herring Run Relief Interceptor was constructed, a segment of 21-inch diameter sewer was abandoned (reference Figure 5.4.1), which connected the Chinquapin Run Interceptor into the original Herring Run Interceptor. Hydraulic simulations indicate that the flows between the two Herring Run Interceptors, where the Chinquapin Run Interceptor currently discharges into the Herring Run Relief Interceptor, are unbalanced. It is recommended that the abandoned 21-inch diameter sewer be reinstated to balance flows between the two Herring Run Interceptors and prevent overflow conditions in the Chinquapin Run Interceptor. Since the existing condition of the 21-inch diameter sewer is unknown, it was assumed that some structural rehabilitation will be required. The hydraulic model conservatively assumes the re-instated sewer will be 18-inch diameter to account for sliplining the existing sewer. The estimated cost for this recommendation is approximately $39,000.

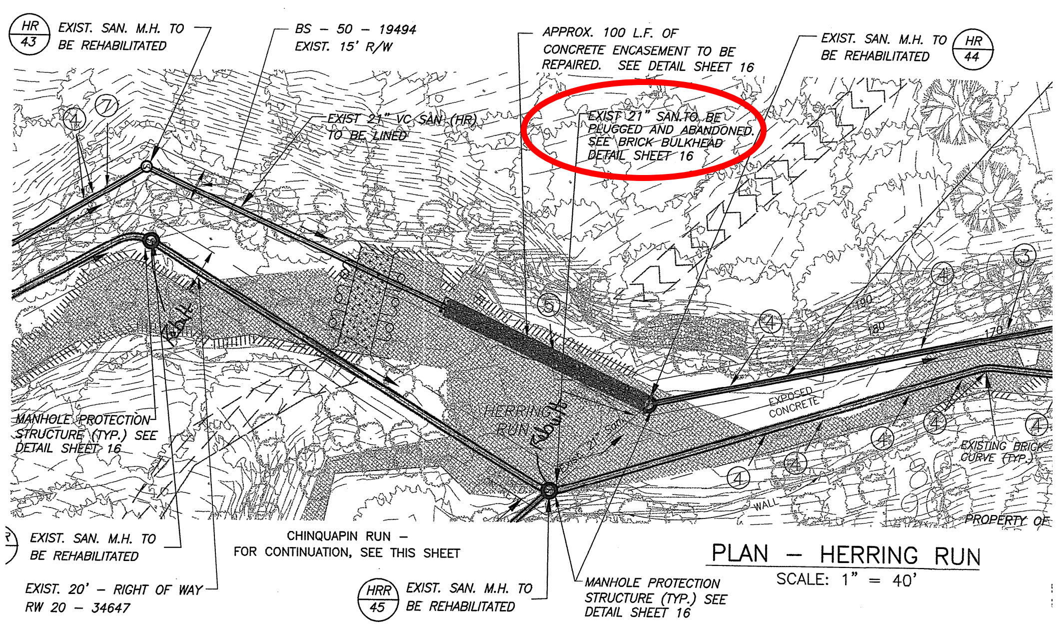


Figure 5.4.1 – Abandonment of Chinquapin Run Interceptor (from SC 761R record drawing W.W.D. 80-49791)

Excessive I/I in the sub-sewershed resulted in several SSOs located along the Chinquapin Run Interceptor. Two alternatives were explored to address the SSOs:

Alternative I – I/I Reduction by Rehabilitation

This alternative includes CIPP lining all sewer pipes (approximately 213,000 LF) and rehabilitation of all manholes (approximately 1,200 EA) in the Chinquapin Run sub-sewershed. Assuming 40 percent reduction in RDII and dry weather infiltration resulting from the rehabilitation project, the hydraulic model predicts that the peak wet-weather flow at the sub-sewershed's discharge location will be reduced by approximately 2 MGD or 13 percent and that all overflows in the Chinquapin Run sub-sewershed will be eliminated. Two manholes along the lower portion of the Chinquapin Run trunk main are recommended to be raised to prevent SSOs at lower-elevation locations. Alternatively, the manhole cover could be sealed in lieu of being raised. The estimated cost for Alternative I is approximately $15,100,000.

Alternative II – Off-line Storage and I/I Reduction by Rehabilitation

Under this alternative, a 0.6 MG storage facility would be constructed at some location along Northwood Drive between The Alameda and Woodbourne Avenue to attenuate wet-weather peak flows. At this location, it may be possible to operate the storage equalization tank by gravity; thereby, minimizing maintenance costs. A 21-inch diameter discharge sewer is proposed for the storage facility. Constructing the storage tank in the upper reaches of the collection system will minimize additional interceptor capacity recommendations. To determine the storage capacity, an initial facility configuration (i.e. elevation, depth, width and length) was assumed. Through iterative analytical reviews of the model simulation results and predicted downstream SSOs, the storage facility capacity was revised and, eventually, finalized. The same iterative process was completed for all proposed storage facilities.

Alternative II also includes CIPP lining of all sewer pipes (approximately 3,000 LF) and rehabilitation of all manholes (13 each) in a small sub-catchment (identified as 33-17-01-

00) area. One manhole (S45QQ1008MH) located on the Chinquapin Interceptor, upstream of the proposed storage tank, is recommended to be sealed to prevent SSO at a lower-elevation location. The estimated cost for Alternative II is approximately $4,700,000.

Based on a cost comparison of the two alternatives, it is recommended that Alternative II be included in the City's corrective action plan.

Tiffany Run

Excessive I/I, recorded at flow meter HR10, produced SSOs at three separate locations during the 2-yr design storm event. It is recommended to perform CIPP lining of all the sewers and rehabilitate all of the manholes in four of the sub-catchments (identified as 33-11-02-02A, B, C and D) located in the southern section of the Tiffany Run sub-sewershed. Due to existing sewer configurations, the sewer between S45AA1008MH and S45AA1011MH discharges in a direction opposing the direction of flow conveyed by the Tiffany Run Interceptor; thereby resulting in surcharged conditions (reference Figure 5.4.2). Therefore, a new 10-inch diameter sewer between S45YY_006MH and S45AA1005MH is recommended to improve hydraulic conditions.

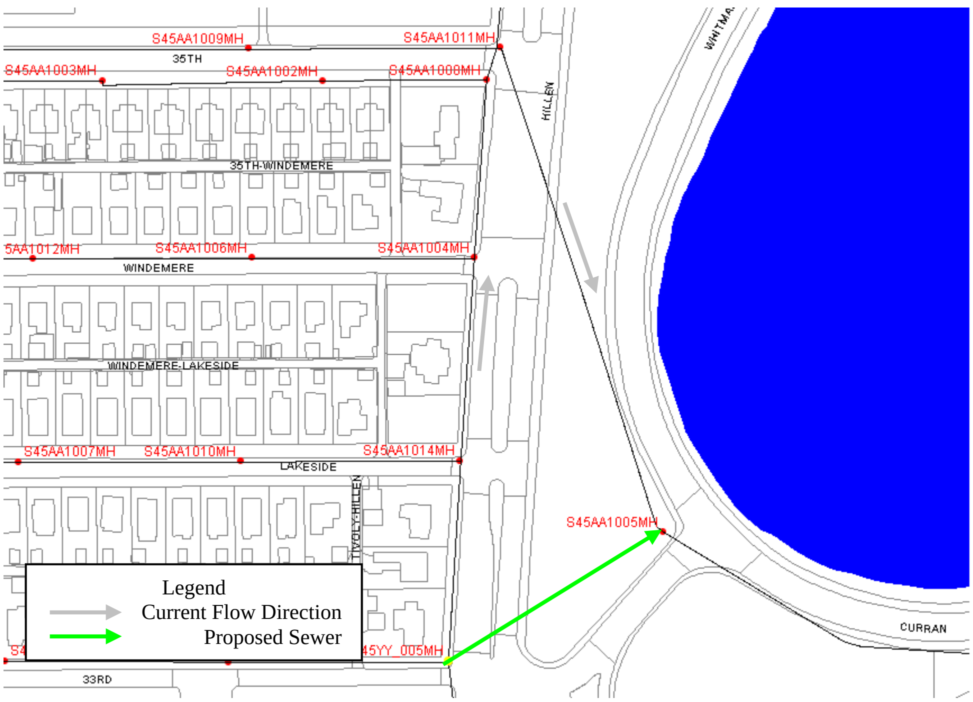


Figure 5.4.2 – Proposed Tiffany Run Hydraulic Improvement

The estimated cost to complete all hydraulic recommendations in the Tiffany Run sub-sewershed is approximately $1,000,000.

Herring Run, West Branch

A parallel 15-inch diameter relief sewer is recommended to convey County flows downstream from the City/County line to a 20-inch diameter sewer segment of the Herring Run West Branch interceptor. Increasing the existing pipe size was considered; however, Sanitary Contract 856 (reference Section 1.4), which is scheduled to begin construction in 2009, precluded any further analysis. The estimated cost to complete all hydraulic recommendations in the Herring Run West Branch sub-sewershed is approximately $2,400,000.

Upper Herring Run

Approximately 1,500 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer and approximately 1,500 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer. Additionally, five manholes (S51UU1008MH, S51UU1012MH, S51UU1013MH, S51UU1016MH and S51UU1017MH) are recommended to be sealed to prevent SSOs at lower-elevation locations. The estimated cost to complete all hydraulic recommendations in the Upper Herring Run sub-sewershed is approximately $1,700,000.

Herring Run

A 3.0 MG offline storage facility is recommended to attenuate peak wet-weather flows in this sub-sewershed. A potential site is in the Herring Run Park near the Harford Road bridge. At this location, it may be possible to operate the storage equalization tank by gravity; thereby, minimizing capital and maintenance costs. Constructing the storage tank in the upper reaches of the collection system minimizes additional interceptor capacity recommendations. Additionally, manholes SS7UU_005MH and SS7UU_00MH7 are recommended to be sealed to prevent SSOs at lower-elevation locations. The estimated cost to complete all hydraulic recommendations in the Herring Run sub-sewershed is approximately $18,600,000.

Moore’s Run

Approximately 800 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer to convey peak wet-weather flows. The estimated cost to complete all hydraulic recommendations in the Moore’s Run sub-sewershed is approximately $450,000.

5-YEAR IMPROVEMENTS

See Map 5.4.2, Herring Run Alternative Analysis (5-Year Storm) for a map depicting the location and extents for each of the following projects. The work described below is additive to the work required for a 2-year event.

Chinquapin Run
To attenuate peak wet-weather flow, a 1.5 MG storage facility is required. The storage tank replaces the 0.6 MG recommended for the 2-year event. Additionally, two sub-catchments (identified as 33-17-11-01 and 33-17-11-02) in the upper reaches of the Chinquapin Run sub-sewershed are recommended for comprehensive rehabilitation. Approximately 730LF of 16-inch diameter sewer and 330 LF of 18-inch diameter sewer must be increased to 21-inch diameter to convey wet-weather flow.

Five manholes (S41II2019MH, S45SS1013MH, S45SS1016MH, S47OO1012MH, S47QQ1008MH) are recommended to be sealed to prevent SSOS at lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Chinquapin Run sub-sewershed is approximately $12,800,000.

Tiffany Run
Approximately 2,700 LF of 10-inch diameter sewer must be increased to 12-inch diameter to convey wet-weather flow. Additionally, three manholes (S43YY_004, S43YY_012, S45YY_002) are recommended to be sealed to prevent SSOs at lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Tiffany Run sub-sewershed is approximately $2,000,000.

Herring Run, West Branch
Approximately 3,600 LF of parallel 21-inch diameter relief sewer is recommended to convey County flows downstream and approximately 1,100 LF of existing sewer is recommended to be replaced with 21-inch diameter sewer. Additionally, four sub-catchments (identified as 33-23-02-00, 33-23-03-00, 33-23-04-01 and 33-23-04-02) are recommended for comprehensive rehabilitation. The estimated cost to complete all hydraulic recommendations in the Herring Run West Branch sub-sewershed is approximately $10,000,000.

Upper Herring Run
A 1.5 million gallon offline storage facility is recommended to attenuate peak wet-weather flows. A potential site is in the near the intersection of Perring Parkway and Woodbourn Avenue near the Mount Pleasant Golf Club. In conjunction with the storage facility, three groups of pipe replacements are recommended:

- Approximately 1,500 Lf of 12-inch diameter sewer is recommended to be increased to 18-inch diameter
- Approximately 1,500 LF of 10-inch diameter sewer is recommended to be increased to 15-inch diameter
- Approximately 1,400 LF of varying-size sewer is recommended to be increased to 15-inch diameter

Two sub-catchments (identified as 33-22-03-00 and 33-22-03-00A) located in the upper reaches of the sub-sewershed are recommended for comprehensive rehabilitation.

The following nine manholes are recommended to be sealed to prevent SSOs at lower-elevation locations:

- S49OO1001MH
- S49OO1028MH
- S51SS1001MH
- S51SS1027MH
- S53UU1015MH
- S53UU1020MH
- S53UU1022MH
- S49MM1001MH
- S49MM1018MH

The estimated cost to complete all hydraulic recommendations in the Upper Herring Run sub-sewershed is approximately $18,900,000.

Herring Run
A 12 MG storage facility is recommended to attenuate peak wet-weather flows. The storage facility would replace the 3.0 MG facility recommended for the 2-year event. The large storage capacity is required to prevent overflows in the 38-inch x 48-inch rectangular-shaped interceptor located downstream of the proposed storage facility. The facility will reduce peak wet-weather flow rate by approximately 50 mgd. A comprehensive I/I reduction program of the tributary area combined with a smaller storage tank was considered; however, the estimated cost for this alternative was approximately $91,000,000 compared to $72,00,000 for the recommended storage tank alternative.

Approximately 1,400 LF of 12-inch diameter sewer is recommended to be increased to 15-inch diameter. Additionally, manhole S55YY_002MH is recommended to be sealed to eliminate overflows at a lower-elevation location. The estimated cost to compete all hydraulic recommendations in the Herring Run sub-sewershed is approximately $75,500,000.

Lower Herring Run
Two manholes (S59MM_003MH and S63GG_013MH) located along the Herring Run Interceptor are recommended to be sealed to prevent wet-weather overflows at low-elevation locations. The estimated cost to complete all hydraulic recommendations in the Lower Herring Run sub-sewershed is approximately $11,000.

Biddison Run
Approximately 500 LF of 8-inch diameter sewer is recommended to be increased to 10-inch diameter. The estimated cost to complete all hydraulic recommendation in the Biddison Run sub-sewershed is approximately $300,000.

Moore’s Run
A comprehensive I/I reduction program is recommended in five sub-catchments (identified as 01-05-31-02, 32-29-00-00, 32-29-00-00A, 32-30-00-00, 32-31-00-00) to attenuate the peak wet-weather flows. The estimated cost to complete all hydraulic recommendations in the Moore’s Run sub-sewershed is approximately $3,500,000.

Lower Moore’s Run
Approximately 500LF of 10-inch diameter sewer is recommended to be increased to 15-inch diameter. The estimated cost to complete all hydraulic recommendations in the Lower Moore’s Run sub-sewershed is approximately $400,000.

Moore's Run Low Level
Various portions of the collection system located in the Moore's Run sub-sewershed have insufficient hydraulic capacity to convey wet-weather flow. Therefore, the following sewer replacements are recommended:

- Approximately 625 LF of 21-inch diameter sewer is recommended to be increased to 27-inch diameter
- Approximately 2,000 LF of 27-inch diameter sewer is recommended to be increased to 30-inch diameter
- Approximately 4,200 LF of 30-inch diameter sewer is recommended to be increased to 33-inch diameter
- Approximately 950 LF of 10-inch diameter sewer is recommend to be increased to 12-inch diameter
- Approximately 210 LF of 10-inch diameter sewer is recommended to be increased to 15-inch diameter

The estimated cost to complete all hydraulic recommendations in the Moore's Run Low Level sub-sewershed is approximately $15,700,000.

10-YEAR IMPROVEMENTS

See Map 5.4.3.2, Herring Run Alternative Analysis (10-Year Storm) for a map depicting the location and extents for each of the following projects. The work described below is additive to the work required for a 5-year event.

Chinquapin Run
Various sewer pipe increases are necessary convey peak wet-weather flow. The following pipe replacements are recommended:

- Approximately 1,400 LF of 12-inch diameter sewer is recommended to be increased to 15-inch diameter
- Approximately 350 LF of 18-inch diameter sewer is recommended to be increased to 24-inch diameter
- Approximately 5,000 LF of 21-inch diameter sewer is recommended to be increased to 24-inch diameter

Additionally, two sub-catchments (identified as 33-17-14-01 and 33-17-14-02) are recommended for comprehensive rehabilitation and manhole S41II2007MH is recommended to be sealed to eliminate overflow at this low-elevation location. The estimated cost to complete all hydraulic recommendations in the Chinquapin Run sub-sewershed is approximately $10,000,000.

Tiffany Run
Five sub-catchments (identified as 33-11-02-01, 33-11-03-00, 33-11-03-00A, 33-11-03-00B, and 33-11-03-00C) are recommended for comprehensive rehabilitation. The estimated cost to complete all hydraulic recommendations in the Tiffany Run sub-sewershed is approximately $4,500,000.

Upper Herring Run
A second storage facility, with a storage volume of 10.5 MG, is recommended to attenuate peak wet-weather flow. A potential site is near the intersection of Herring Run Drive and Echodale Avenue in the Mount Pleasant Park. The storage capacity is required to prevent overflows in the Herring Run original and relief interceptors.

The following sewer replacements are recommended to convey peak wet-weather flow:

- Approximately 1,500 LF of 10 and 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer.
- Approximately 5,300 LF of 12 and 15-inch diameter sewer is recommended to be replaced with 18-inch diameter sewer
- Approximately 2,000 LF of 18-inch diameter sewer is recommended to be replaced with 21-inch diameter sewer
- Approximately 250 LF of 21-inch diameter sewer is recommended to be replaced with 24-inch diameter sewer
- Approximately 34 LF of 21-inch diameter and 434 LF of 42-inch diameter sewer is required to convey flow to/from the proposed storage facilities

Three manholes (S51EE2002MH, S51EE2006MH and S55UU1011MH) are recommended to be sealed to prevent SSOs at lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Upper Herring Run sub-sewershed is approximately $104,100,000.

Herring Run

Manholes S55WW_021MH and S55YY_016MH are recommended to be sealed to prevent SSOs at lower-elevation locations. The estimated cost to complete all hydraulic recommendations in the Herring Run sub-sewershed is approximately $11,000.

Herring Run Low Level

Approximately 885 LF of 8 and 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer. The estimated cost to complete all hydraulic recommendations in the Herring Run Low Level sub-sewershed is approximately $700,000.

Biddison Run

Approximately 450 LF of 8-inch diameter sewer and 1,500 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer. The estimated cost to complete all hydraulic recommendations in the Biddison Run sub-sewershed is approximately $1,500,000.

Moore's Run

Four sub-catchments (identified as 32-11-00-00B, 32-25-00-00, 32-27-00-00, 32-28-00-00) in the Moore's Run sub-sewershed are recommended for comprehensive rehabilitation.

Additionally, various sewer replacements are recommended as summarized below:

- Approximately 500 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter
- Approximately 1,100 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter
- Approximately 2,200 LF of 15-inch diameter sewer is recommended to be replaced with 18-inch diameter
- Approximately 500 LF of 18-inch diameter sewer is recommended to be replaced with 21-inch diameter
- Approximately 2,000 LF of 21-inch diameter sewer is recommended to be replaced with 24-inch diameter

The estimated cost to complete all hydraulic recommendations in the Moore's Run sub-sewershed is approximately $9,200,000.

Lower Moore's Run
The Moore's Run interceptor has insufficient capacity to convey peak wet-weather flow; therefore, a second storage facility is recommended. An additional 1.0 MG storage facility is recommended immediately upstream of the Moore's Run Siphon. The proposed site is near Moravia Road, between Sinclair Lane and Harbor Tunnel (Interstate 895). Approximately 74 LF of 48-inch diameter sewer is required to convey flow to/from the storage facility. The estimated cost to complete all hydraulic recommendations in the Lower Moore's Run sub-sewershed is approximately $8,700,000.

Moore's Run Low Level
A 2.0 MG storage facility is recommended between the Harbor Tunnel and Sinclair Lane, near Todd Avenue. Approximately 146 LF of 48-inch diameter sewer is required to convey flow to/from the facility. Additionally, the following sewer replacements are recommended to address insufficient hydraulic capacity in the collection system:

- Approximately 800 LF of 10-inch diameter sewer to be replaced with 12-inch diameter sewer
- Approximately 226 LF of 10-inch diameter sewer to be replaced with 18-inch diameter sewer
- Approximately 2,500 LF of 15-inch diameter sewer to be replaced with 18-inch diameter sewer
- Approximately 64 LF of 12-inch diameter sewer to be replaced with 18-inch diameter sewer
- Approximately 2,100 LF of 15-inch diameter sewer to be replaced with 18-inch diameter sewer

In addition to the storage and conveyance upgrades, it is recommended that a comprehensive I/I reduction program be completed in the following sub-catchments:

- 01-05-28-00
- 22-29-05-00
- 22-32-04-00
- 26-09-00-00
- 26-11-00-00
- 26-13-00-00A
- 29-07-00-00A

The estimated cost to complete all hydraulic recommendations in the Moore's Run Low Level sub-sewershed is approximately $24,400,000.

<u>15-YEAR IMPROVEMENTS</u>

See Map 5.4.4, Herring Run Alternative Analysis (15-Year Storm) for a map depicting the location and extents for each of the following projects. The work described below is additive to the work required for a 10-year event.

Chinquapin Run
To convey the peak wet-weather flows, the following sewer replacements are recommended:

- Approximately 660 LF of 8-inch diameter sewer is recommended to be replaced with 10-inch diameter sewer

- Approximately 500 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer
- Approximately 800 LF of 12-inch diameter sewer is recommended to be replaced with 18-inch diameter sewer
- Approximately 2,400 LF of 16-inch diameter sewer is recommended to be replaced with 18-inch diameter sewer

Two manholes (S43UU1028MH and S47QQ1005MH) are recommended to be sealed to prevent SSOs at lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Chinquapin Run sub-sewershed is approximately $3,800,000.

Tiffany Run
To convey peak wet-weather flow, approximately 1,300 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter. Additionally, 15 sub-catchments in are recommended for comprehensive rehabilitation. The sub-catchments are identified as

- 33-11-02-02
- 33-11-04-00
- 33-11-04-00A
- 33-11-05-00
- 33-11-06-00
- 33-11-06-00A
- 33-11-06-00B
- 33-11-07-00
- 33-11-08-00A
- 33-11-08-00B
- 33-11-09-00
- 33-11-09-00A
- 33-11-10-00
- 33-11-11-00A
- 33-11-11-00B

The estimated cost to complete all hydraulic improvements in the Tiffany Run sub-sewershed is approximately $13,400,000.

Herring Run West Branch
Approximately 4,500 LF of 21-inch diameter sewer previously recommended to convey the 10-year storm event wet-weather flow is recommended to be replaced with 24-inch diameter sewer. Additionally, three manholes (S47GG2018MH, S47II2012MH and S49GG2009MH) are recommended to be sealed to prevent SSOs at lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Herring Run West Branch sub-sewershed is approximately $7,000,000.

Upper Herring Run
A 1.9 MG storage facility is recommended to attenuate the peak wet-weather flow. The storage facility replaces the 1.5 MG storage facility that was originally recommended for the 5-year storm event.

To convey the peak wet-weather flow, the following sewer replacements are recommended:

- Approximately 600 LF of 18-inch diameter sewer is recommended to be replaced with 21-inch diameter sewer
- Approximately 109 LF of 20-inch diameter sewer is recommended to be replaced with 21-inch diameter sewer
- Approximately 520 LF of 20-inch diameter sewer is recommended to be replaced with 24-inch diameter sewer
- Approximately 2,300 LF of 21-inch diameter sewer is recommended to be replaced with 24-inch diameter sewer
- Approximately 500 LF of 24-inch diameter sewer is recommended to be replaced with 33-inch diameter sewer
- Approximately 800 LF of 27-inch diameter sewer is recommended to be replaced with 33-inch diameter sewer
- Approximately 800 LF of 30-inch diameter sewer is recommended to be replaced with 33-inch diameter sewer
- Approximately 2,700 LF of 33-inch diameter sewer is recommended to be replaced with 36-inch diameter sewer

Seven sub-catchments (33-13-05-00A, 33-21-00-00A, 33-21-00-00B, 33-21-01-00, 33-21-02-00A, 33-21-02-00B and 33-22-01-00) are recommended for comprehensive rehabilitation and two manholes (S61EE2005MH and S51EE2010MH) are recommended to be sealed to prevent SSOs at these lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Upper Herring Run sub-sewershed is approximately $26,200,000.

Herring Run

Approximately 1,800 LF of 8-inch diameter sewer is recommended to be replaced with 10-inch diameter sewer to convey wet-weather flow from the 12 MG storage facility. Eight sub-catchments (33-02-00-00, 33-03-00-00, 33-06-00-00, 33-07-00-00, 33-10-01-00, 33-10-02-00A, 33-10-02-00B and 33-10-02-00C) are recommended for comprehensive rehabilitation and two manholes (S53YY_005MH and S55YY_010MH) are recommended to be sealed to prevent SSOs at lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Herring Run sub-sewershed is approximately $10,300,000.

Lower Herring Run

A 5.5 MG storage facility is recommended to attenuate the peak wet-weather flow. A potential tank site is an open space area near Orville Ave and Federal Street, immediately upstream of the Upper Herring Run Siphons. Approximately 200 LF of 24-inch diameter sewer is required to convey flow to/from the facility.

One sub-catchment (33-00-00-00) is recommended for comprehensive rehabilitation and six manholes (S59KK_002MH, S61II_003MH, S61II_018MH, S61KK_002MH, S61KK__003MH and S61KK_034MH) are recommended to be sealed to prevent SSOs at these lower-elevation locations.

The estimated cost to complete all hydraulic recommendations in the Lower Herring Run sub-sewershed is approximately $47,900,000.

Belmar
Two manholes (S65II1005MH and S65II1027MH) are recommended to be sealed to prevent SSOs at lower-elevation locations. The estimated cost to complete all hydraulic recommendations in the Belmar sub-sewershed is approximately $11,000.

Moore's Run
Approximately 1,800 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer and approximately 1,600 LF of 21-inch diameter sewer is recommended to be replaced with 24-inch diameter sewer.

The estimated cost to complete all hydraulic recommendations in the Moore's Run sub-sewershed is approximately $3,900,000.

Moore's Run Low Level
Four sub-catchments (22-29-05-00, 26-02-00-00, 26-03-00-00 and 26-09-00-00) are recommended for comprehensive rehabilitation and nine manholes (S69AA1030MH, S69QQ_013MH, S69UU_006MH, S69WW_010MH, S61KK_035MH, S63OO_025MH, S63OO_026MH, S63QQ_031MH and S65QQ_031MH) are recommended to be sealed to prevent SSOs at lower-elevation locations. Additionally, some sewer replacements are recommended to convey peak wet-weather flow:

- Approximately 60 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer
- Approximately 900 LF of 15-inch diameter sewer is recommended to be replaced with 18-inch diameter sewer
- Approximately 700 LF of 33-inch diameter sewer is recommended to be replaced with 36-inch diameter sewer

The estimated cost to complete all hydraulic recommendations in the Moore's Run Low Level sub-sewershed is approximately $5,600,000.

Quad Avenue
The Quad Avenue Pumping Station does not have adequate capacity to convey the peak wet-weather flow. Therefore, the pumping station capacity is recommended to be increased by 10 million gallons per day. The existing 36-inch diameter force main has sufficient capacity to convey the peak wet-weather flow. The estimated cost to complete all hydraulic recommendations in the Quad Avenue sub-sewershed is approximately $11,400,000.

20-YEAR IMPROVEMENTS

See Map 5.4.5, Herring Run Alternative Analysis (20-Year Storm) for a map depicting the location and extents for each of the following projects. The work described below is additive to the work required for a 15-year event.

Chinquapin Run
Approximately 850 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer. The estimated cost to complete all hydraulic recommendations in the Chinquapin Run sub-sewershed is approximately $800,000.

Upper Herring Run
To convey peak wet-weather flow, the following sewer replacements are recommended:

- Approximately 75 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer
- Approximately 180 LF of 15-inch diameter sewer is recommended to be replaced with 18-inch diameter sewer
- Approximately 1,400 LF of 18-inch diameter sewer is recommended to be replaced with 21-inch diameter sewer
- Approximately 300 LF of 24-inch diameter sewer is recommended to be replaced with 27-inch diameter sewer

The estimated cost to complete all hydraulic recommendations in the Upper Herring Run sub-sewershed is approximately $5,300,000.

Herring Run Low Level
Approximately 400 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer and approximately 1,800 LF of 15-inch diameter sewer is recommended to be replaced with 18-inch diameter sewer to convey peak wet-weather flow. The estimated cost to complete all hydraulic recommendations in the Herring Run Low Level sub-sewershed is approximately $1,900,000.

Biddison Run
Approximately 700 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer. The estimated cost to complete all hydraulic recommendations in the Biddison Run sub-sewershed is approximately $600,000.

Belmar
Approximately 1,000 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer. The estimated cost to complete all hydraulic recommendations in the Belmar sub-sewershed is approximately $800,000.

Moore's Run
Various sewer replacements are recommended to convey peak wet-weather flow:

- Approximately 1,900 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer
- Approximately 400 LF of 10-inch and an additional 400 LF of 12-inch diameter sewers are recommended to be replaced with 15-inch diameter sewer
- Approximately 300 LF of 24-inch diameter sewer is recommended to be replaced with 27-inch diameter sewer

The cost to complete all hydraulic recommendations in the Moore's Run sub-sewershed is approximately $2,700,000.

Moore's Run Low Level
The following sewer replacements are recommended to convey peak wet-weather flow:

- Approximately 64 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer
- Approximately 1,400 LF of 15-inch diameter sewer is recommended to be replaced with 18-inch diameter sewer

- Approximately 1,900 LF of 18-inch diameter sewer is recommended to be replaced with 21-inch diameter sewer
- Approximately 2,300 LF of 21-inch diameter sewer is recommended to be replaced with 24-inch diameter sewer
- Approximately 180 LF of 27-inch diameter sewer is recommended to be replaced with 30-inch diameter sewer
- Approximately 2,100 LF of 30-inch diameter sewer is recommended to be replaced with 33-inch diameter sewer
- Approximately 150 LF of 33-inch diameter sewer is recommended to be replaced with 36-inch diameter sewer
- Approximately 2,800 LF of 36-inch diameter sewer is recommended to be replaced with 42-inch diameter sewer

The estimated cost to complete all hydraulic recommendations in the Moore's Run Low Level sub-sewershed is approximately $18,400,000.

Quad Avenue
To convey peak wet-weather flow, approximately 500 LF of 36-inch diameter sewer is recommended to be replaced with 42-inch diameter sewer. The existing 36-inch diameter force main has sufficient hydraulic capacity to convey the peak wet-weather flow. The estimated cost to complete all hydraulic recommendations in the Quad Avenue sub-sewershed is approximately $1,000,000.

The total improvement costs per design storm return period are presented in Table 5.4.1. The table shows the cumulative cost to convey each year event's flows and the additional cost required on top of the previous year's storm.

Table 5.4.1 - Total Estimated Improvement Costs for Herring Run (in millions of dollars)

Projected		5 Year		10 Year		15 Year		20 Year	
Year	2 Year	Add.	Cum.	Add.	Cum.	Add.	Cum.	Add.	Cum.
2008	$40.68	$139.03	$179.71	$161.98	$341.69	$129.19	$470.88	$31.17	$502.05
2009	$43.53	$148.76	$192.29	$173.32	$365.61	$138.23	$503.84	$33.35	$537.19
2010	$46.57	$159.18	$205.75	$185.45	$391.20	$147.91	$539.11	$35.69	$574.80
2011	$49.83	$170.32	$220.15	$198.43	$418.58	$158.26	$576.85	$38.18	$615.03
2012	$53.32	$182.24	$235.56	$212.32	$447.89	$169.34	$617.23	$40.86	$658.09
2013	$57.06	$195.00	$252.05	$227.19	$479.24	$181.20	$660.43	$43.72	$704.15
2014	$61.05	$208.65	$269.70	$243.09	$512.78	$193.88	$706.66	$46.78	$753.44
2015	$65.32	$223.25	$288.57	$260.10	$548.68	$207.45	$756.13	$50.05	$806.18
2016	$69.90	$238.88	$308.78	$278.31	$587.09	$221.97	$809.06	$53.56	$862.62
2017	$74.79	$255.60	$330.39	$297.79	$628.18	$237.51	$865.69	$57.30	$923.00

6.0 Geographic Information System

6.1 Overview of GIS

The City of Baltimore maintains a robust Geographic Information System (GIS) representing the wastewater infrastructure. The GIS is housed in an ESRI format Geodatabase and leverages the enterprise capabilities of ArcSDE. An integral part of the sewershed study is the update of the GIS to represent the existing conditions at the time of the study. These updates provided to the City were considered "Core" data deliveries as they are the primary or core repository of data representing the wastewater infrastructure. This is in comparison to "non-core" data which was the supplemental data provided to the City such as manhole inspection reports, CCTV video, etc.

This section describes the City's GIS system; describes the methods and procedures used during the project to update the system; and the quality assurance procedures performed to verify the accuracy of the work performed.

The wastewater utility geodatabase is comprised of three thematic groups of features:

- Lines Thematic Group – contains wastewater features that can be represented as lines whose direction indicates the direction of flow. These line features make up the foundation of the wastewater network. All features in this thematic group participate in the geometric network. These features include:
    - House Connection (line)
    - Sewer (line)

- Features Thematic Group – contains wastewater features that can be represented as points, lines and/or polygons. The features in this thematic group do not affect flow and will not participate in the geometric network. Traces and other network analysis operations do not consider these entities, yet they are captured in the database to provide a more complete representation of the system. These features include:
    - Casing (polygon)
    - Facility (polygon)
    - Lamphole (point)
    - Manhole Cover (point)
    - Structure (polygon)

- Devices Thematic Group – contains wastewater features that can be represented as points. All features in this thematic group participate in the geometric network. These features include:
    - Manhole Junction (point)
    - Meter Station (point)
    - Pump Station (point)
    - Treatment Plant (point)
    - Bend (point)
    - Valve (point)
    - House End (point)
    - House Intersection (point)
    - House Sewer Intersection (point)
    - Sewer End (point)

- Sewer Intersection (point)

The following graphic summarizes the feature objects in the City's wastewater GIS.

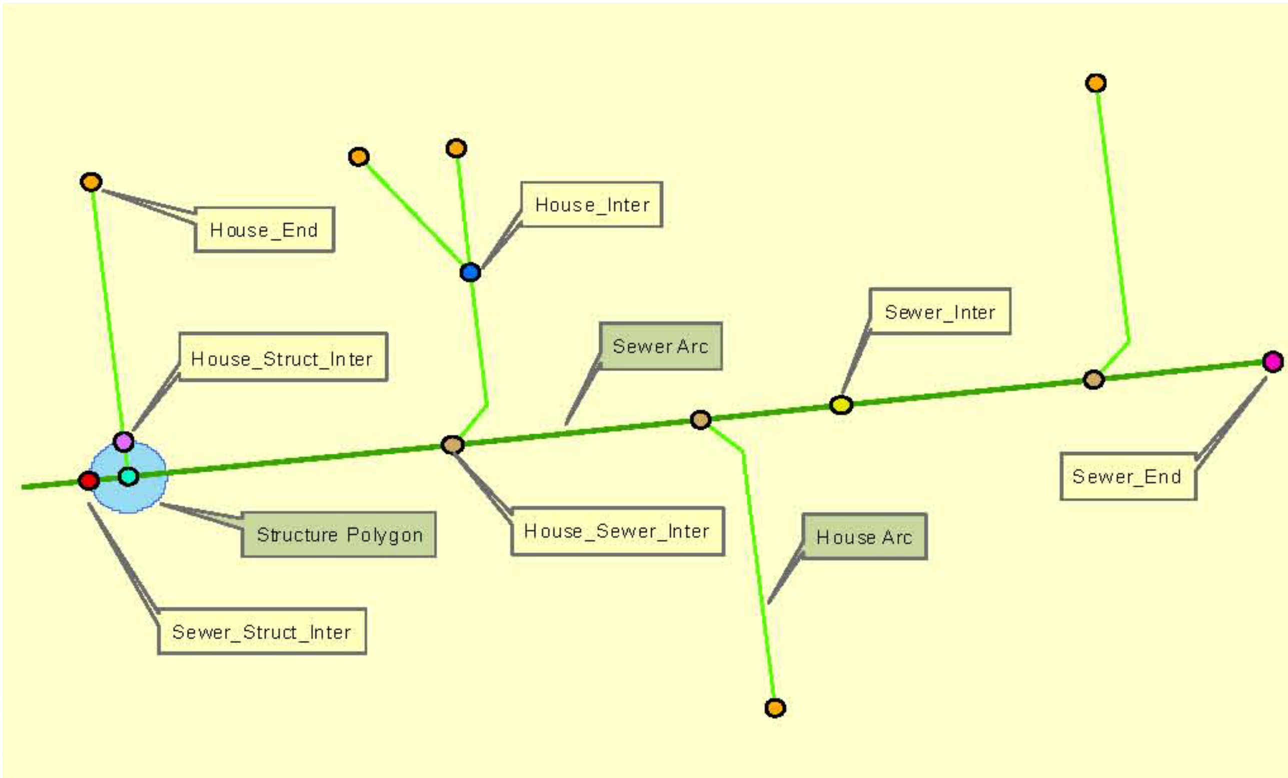


Figure 6.1.1 – GIS Feature Group Summary

6.2 Field Data and GIS Integration

The Sewershed Study and Evaluation project involved extensive field activities which generated significant amounts of non-core data to be used to update the core GIS. Specifically, the non-core data generated was:

- Manhole Inspection Data
- GPS Survey Data
- Closed Circuit Television (CCTV) Inspection Data
- Smoke Testing
- Dyed Water Testing Data

The majority of the spatial and attribute edits made to the wastewater geodatabase were based on information extracted from these non-core datasets. When current conditions could not be established through these sources, additional engineering contract document research was performed to populate the GIS. The following is further description regarding the field collected data and its use in updating the GIS.

Manhole Inspections
Manhole inspections were performed on 6,689 manholes in the Herring Run sewershed. Information was collected using a custom designed Manhole Inspection Application

Software (MIAS) application. MIAS allows field crews to collect detailed attribute information about the physical characteristics of a manhole, its sewer connections, and the manhole's surrounding environment. In addition to characteristics such as size, shape, and material, the application records the condition and infiltration properties of the manhole's features. The MIAS application captures inventory and condition information for the following manhole components:

- Location
- Environment
- Cover
- Frame
- Chimney/Stack
- Corbel
- Barrel
- Bench
- Channel
- Pipe Connections

The unique identifier used in both the GIS and MIAS datasets is the MANHOLE_ID field. This common field allowed for database joins which facilitated integration of the manhole inspection field information directly into wastewater feature attribute fields.

In addition to data collected in the MIAS application, inspectors also recorded changes between actual field conditions and the current GIS information on paper plots of the GIS data. This provided a convenient medium to record additional remarks that were then later modified in the GIS by technicians.

During each field inspection, the manhole horizontal location was compared to the location recorded in the wastewater geodatabase. Manhole locations that were greater than five (5) feet from the GIS location were surveyed or triangulated from physical landmarks identified in the GIS topographical photography.

Roughly 47,100 manhole inspection photos were taken during the manhole inspections in the Herring Run sewershed. The MIAS application and other GIS tools provided easy access to these photos for use in checking and validating the manhole information being entered into the database.

GPS Manhole Surveys

A total of 1,400 survey-grade GPS survey locations of manhole covers were completed during the project. These GPS locations were used to position key manhole features and to establish the rim elevation stored in the manhole cover GIS feature class.

The GPS rim elevations were used along with depths measured during the manhole inspection, from the rim down to the invert of each pipe connecting manhole, to establish pipe invert elevations in the Sewer feature layer.

Rim elevations for manholes that were not GPS surveyed were extracted from a City supplied Digital Elevation Model (DEM) layer. Only manholes not included in the hydraulic model were assigned an elevation using this DEM technique. The ground to rim height, measured in the manhole inspection was added (or subtracted) from the calculated DEM elevation before merging the elevation values into the GIS rim elevation attribute field.

CCTV Inspections
The Herring Run sewershed study plan team completed roughly 8,100 individual CCTV sewer inspections. The up and down nodes for each CCTV survey were verified that they link to a valid GIS manhole, lamphole or SewerEnd features that represent the starting and ending locations of the survey.

With the data relationship established, the CCTV surveys, manhole inspections (MIAS database) and the GIS were compared to assist in GIS attribute updating.

The CCTV surveys were invaluable in the GIS updating process by enabling Engineers and GIS technicians to:

- Locate previously unknown buried manholes and to incorporate them into the GIS at their proper location.
- Establish the existence of manholes in the GIS
- Identify the proper location of changes or fixtures in the system:
    - Size changes
    - Material changes
    - Angular changes
    - Tees and Wyes (sewer mains connecting without a manhole)

Smoke and Dyed Water Testing
Sewer connectivity findings determined by smoke testing were incorporated into the wastewater geodatabase. Only constructed overflows and illegal stormwater connections that were identified by smoke testing and confirmed by dye testing were added to the geodatabase. In total, 759 smoke testing reports were generated and 65 dyed water testing reports were generated for the Herring Run Sewershed.

6.3 Office Research and GIS Updates

The compilation of field collected data allowed GIS technicians to update a significant amount of the GIS representation of the wastewater infrastructure. Prioritization of the applicability of the variety of sources was performed on an attribute by attribute basis based upon the guidance provided by the City's Baltimore Sewer Evaluation Standards manual (BaSES). Some features or attributes could not be adequately quantified using the collected field information and required additional research of Baltimore's record plat maps and engineering contract drawings.

Using standard ESRI editing functionality in the ArcGIS platform as well as custom tools for GIS updates, GIS technicians utilized the sources available to them to update the wastewater geodatabase. As tiles in the City's standard grid index were completed and quality assurance approved, the data was synchronized back to the City for quality control review by the data clearinghouse.

6.4 QA/QC Review and Procedures

A variety of procedures were performed for quality assurance and quality control of the wastewater geodatabase.

- Oversight and manual spot checks by engineers were performed for quality assurance.

- ArcInfo topology checks to verify feature topology; feature snapping; flow tracing; and location of duplicate features.
- Database queries to compare the GIS datasets with the other non-core data sources were executed to review for anomalies.
- An automated suite of 171 quality control tests built in the ESRI Production Line Tool Set (PLTS) platform were run against the dataset both by the sewershed consultant as well as the data clearinghouse. These tests perform a variety of checks on features and feature attributes, including: domain validation, attribute, logical, spatial, and topologic.

6.5 GIS Certification

The Herring Run Sewershed team has followed the processes described above and those described in more detail in the City BaSES manual to update the City of Baltimore's wastewater GIS for the Herring Run Sewershed. The City of Baltimore and the Herring Run Sewershed team are hereby certifying that the GIS data represented in the Herring Run sewershed portion of the City's GIS provides the necessary data for the adherence of Paragraph 14 Information Management System Program.

The Herring Run Sewershed portion of the City's GIS is the best assessment of current conditions achievable with the available technology and source data. Current conditions are defined as of April, 2009. Furthermore, the City of Baltimore has instituted processes to ensure that should changes to the sewer infrastructure in the Herring Run Sewershed occur the GIS will be updated within 90 days of the changes.

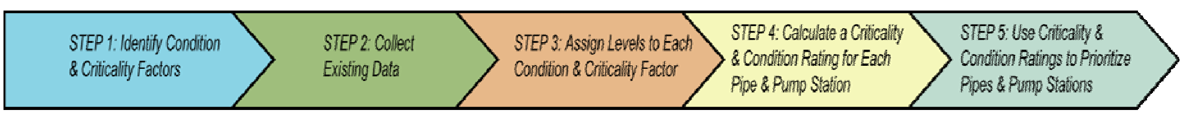
7.0 Recommendations

As required by the Consent Decree (CD), each Sewershed Study and Plan is required to identify specific improvements or other corrective actions needed to address deficiencies identified during the sewershed evaluation to aid in reducing rainfall dependent inflow and infiltration (RDI/I) contributing to sanitary sewer overflows (SSO's) or combined sewer overflows (CSO's); address deficiencies identified during the hydraulic analyses and address other deficiencies that contribute to SSO's or CSO's in the Herring Run Sewershed. This section outlines how the data analysis, evaluation and the decision-making criteria were utilized to identify and prioritize improvements within the Herring Run Sewershed.

7.1 Decision Making Criteria

As part of the sewershed studies, the City developed a condition and criticality protocol that provides a framework for a continuous rehabilitation strategy of all collection system components based on both criticality (consequence of failure) and condition (probability of failure). Assets whose failure can have large impacts on the community and the environment and whose condition is the poorest will receive a higher criticality rating and will receive attention sooner. Assets that receive a lower criticality rating will receive some level of continued monitoring but no immediate action or rehabilitation at this time.

The prioritization process consists of five steps illustrated below.



Identify the condition and criticality factors that will be used to assess the sewer system. These factors have been identified and include proximity to human population, to bodies of water, to forests, and to wildlife habitat that could potentially be affected by a sewer system failure.

Collect data that will be used to evaluate each factor including CCTV inspection data, manhole inspection data, pumping station inspection data, GIS data, results of hydraulic modeling, and sewer complaint data.

Assign different levels to each factor so that pipes, manholes, and pumping stations can be differentiated in terms of their condition or criticality.

Assign a condition and criticality rating for each pipe, manhole and pumping station. The ratings are assigned by using the level assigned to each factor and the relative importance of each factor.

Use the ratings to prioritize the system and determine short-term and long-term rehabilitation projects.

For each category, factors were used to measure the condition and criticality of every asset. Table 7.1.1 below lists the condition and criticality categories and factors that were considered.

Table 7.1.1 - Condition and Criticality Factors

Criticality Category	**Criticality Factor**
Quantity of Flow Conveyed	Pipe Diameter Pump Station Capacity
Transportation/Urban Impact	Proximity to Historic Areas Proximity to Community Areas (Parks, Schools, Etc.) Traffic Conditions Proximity to Railroad Easements
Environmental Impact	Proximity to Forested Areas Proximity to Waterways / Streams Proximity to Wetlands
Public Health Impact	Population Density Proximity to Floodplains SCADA / Warning Systems
Ease of Emergency Repair	Accessibility Ability to Re-route Flow Proximity to City Conduits Building Encroachment System Redundancy Emergency Power Ability to Bypass Flow Pipe Depth
Condition Category	**Condition Factor**
Structural Condition	Structural Pipe Rating Manhole Inspection Rating
Maintenance Frequency	O&M Pipe Rating Number of SSOs or CSOs Known Maintenance Issues Documented RDI/I Rates
Capacity	Need for Additional Capacity

Each condition and criticality factor is assigned a rating from 1 to 5. The purpose of assigning ratings to each condition and criticality factor is to differentiate sewer pipes, manholes, and pumping stations in terms of the consequences and probability of their failure.

The rating assigned increases as the consequence of failure or probability of failure increases. For example, a break in a 24-inch diameter interceptor sewer can result in more wastewater being released than a break in an 8-inch diameter collector sewer. Therefore, the larger diameter pipe has a higher criticality rating based on the amount of flow being conveyed. The 24-inch diameter interceptor sewer would be assigned a higher rating (5) for the ‘Quantity of Flow Conveyed’ criticality factor and the 8-inch diameter collector sewer would be assigned a lower rating (1) for the same factor.

After a rating of 1 through 5 is assigned, an overall criticality rating and an overall condition rating is calculated for each system component. The criticality rating is calculated using the highest individual level assigned to any of the criticality factors multiplied by a relative importance value. The condition rating is equal to the highest individual NASSCO PACP or MACP rating assigned to any of the condition factors. The relative importance value for the criticality rating is the weighting, expressed as a percentage, applied to each criticality factor to calculate an overall rating. The relative importance values are the same for each collection system component and are presented in Table 7.1.2.

Table 7.1.2 - Criticality Factor Relative Importance Values

Criticality Factors	Relative Importance Value
Quantity of Flow Conveyed	30%
Transportation/Urban Impact	15%
Environmental Impact	20%
Public Health Impact	15%
Ease of Emergency Repair	20%
Total	**100%**

The final assessment culminates in a rating of 1 through 5 for criticality and utilizing NASSCO's MACP or PACP, a 1 through 5 rating for condition, which determines priorities for repairs or continuous condition assessment or monitoring. This approach allows the City to focus their available resources and funding on the most immediate system repair needs. Figure 7.1.1 is a matrix showing the recommended course of action for each sewer system component based on the combination of condition and criticality. The vertical 1 through 5 rating scale is for condition and the horizontal 1 through 5 scale is a rating for an asset's criticality within the collection system.

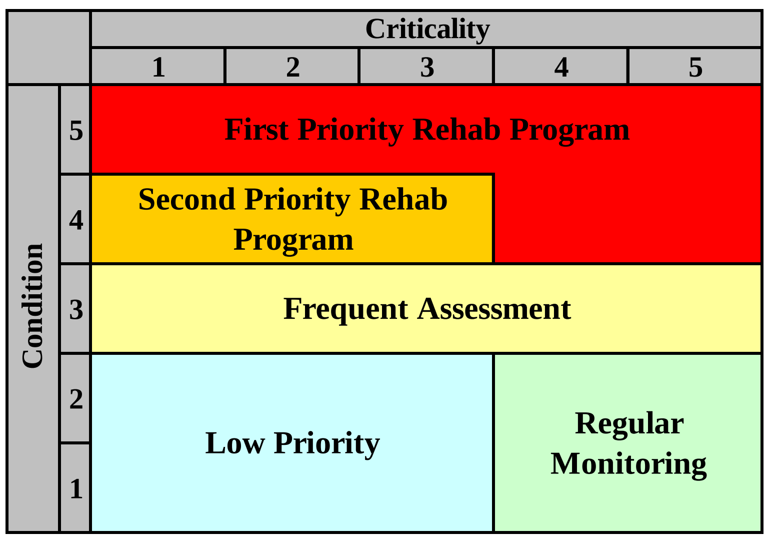


Figure 7.1.1 – Condition/Criticality Matrix

Each of the recommended courses of action is briefly described in more detail below. The specific improvement projects and/or other corrective actions will vary based on the type of collection system component (gravity sewer, force main, manhole, or pumping station).

First Priority Rehabilitation Program

Assets that receive a condition rating of 5 regardless of criticality, and assets that receive a condition rating of 4 and criticality rating of 4 and 5 are placed at the highest priority for rehabilitation, repair or replacement. These assets lack hydraulic capacity, contribute to system inflow and infiltration (I/I) and/or are likely to fail in the near future. They present the potential for SSO's or could create a major disruption in service and potentially impact the environment and/or public health if not addressed.

Second Priority Rehabilitation Program
Assets that receive a condition rating of 4 and criticality rating of 1, 2, or 3 will be given second priority in the rehabilitation program. These assets contribute to system I/I, and are likely to continue to deteriorate and to require attention in the foreseeable future.

Frequent Assessment
Assets that are in fair physical condition (PACP/MACP condition rating of 3), should have their condition assessed frequently, every 2 to 3 years regardless of the criticality rating. The purpose of frequent assessment is to check if the condition has deteriorated to a point that the asset would need to be moved to a higher priority.

Regular Monitoring
The assets in the regular monitoring category are typically in serviceable condition (PACP/MACP condition rating of 1 or 2), but received a high criticality rating of 4 or 5. These assets should be checked every 3 to 5 years.

Low Priority
The low priority category includes assets that are believed to be in good condition (PACP/MACP condition rating of 1 to 2), and received a lower criticality rating of 1 through 3. The assets in this category will receive some level of inspection (once every 5 to 10 years) to verify that their conditions are not continuing to deteriorate.

7.2 Proposed Improvements

It should be noted that the interrelationship between the City's sewersheds, known as boundary conditions, must be understood and carefully considered before significant hydraulic repairs are completed. The Jones Falls, Herring Run, High Level, Low Level, and Dundalk sewersheds flow into the Outfall sewershed. These six sewersheds are connected and hydraulically interdependent, creating "boundary" conditions that must be defined and considered for hydraulic modeling. Ultimately, the collection system within the six interdependent sewersheds should be modeled as one. The City has begun development of a model to accomplish the system-wide modeling, which will be refined and improved as the individual sewershed studies complete calibration of their respective sewershed models. This Plan provides certain recommended improvements that would be implemented by the City in accordance with a proposed schedule. However, the Plan should not be considered final and may require amendment as necessary once the system-wide hydraulic model is completed and system-wide simulations are performed. System-wide simulations could alter the recommendations identified by an individual Sewershed Study and Plan.

Once the sewer system improvement projects and/or other corrective actions required to address deficiencies were identified and ranked based on the criticality and condition ratings; assets that received a condition rating of 5, regardless of criticality, were included in a "First Priority" corrective action plan. Assets that had a condition rating of 4 and a criticality rating of 4 or 5 were also included in a "First Priority" corrective action plan. Assets that received a condition rating of 4, but were not considered to be as critical (3 or less) were included in the "Second Priority" corrective action plan.

Asset prioritization was developed with consideration that all proposed improvement projects required to eliminate SSO's must be completed before January 1, 2016 as stipulated by the CD. These assets included First and Second Priority manholes and sanitary sewers, identified SSO structures, and recommended hydraulic improvements to the collection system. These proposed improvement projects are as follows:

7.2.1 Sanitary Sewer Overflow Structure Identification and Elimination

As a requirement of the City's CD, the Sewershed Study and Plan is required to identify undocumented SSO structures. Investigations completed in support of this report have identified one (1) undocumented SSO structure in the Herring Run sub-sewershed that requires elimination. The structure is located at the intersection of Shannon Drive and Brehms Lane. The manhole is identified as S57UU_007MH in the supporting documents completed for this project. The overflow, which has been numbered SSO 137, has been metered since its discovery in 2009 to record any activity. However, flow data is not available at this time. Regardless of prior inactivity at this SSO structure, it will be placed on the City's First Priority corrective action plan for removal.

7.2.2 Structural Deficiencies Identified

Proposed Manhole Improvements (Condition Rating Grade 4 & 5):
Table 7.2.2.1 shows a listing of all manholes inspected within the Herring Run Sewershed based on condition ratings and further isolated into sub-sewersheds. Manhole recommendations were based on a review of the field inspection reports. Table 7.2.2.2 quantifies the number of manholes that received a MACP condition rating score of 4 or 5 and are recommended for repairs. These manholes are further separated by sub-sewersheds for contract scheduling.

Table 7.2.2.1 - Condition Ratings - Manholes by Sub-Sewershed

		Herring Run Sub-Sewershed – Manhole Condition Ratings (1 through 5)																									
		HRWB		UHR		HR		LHR		CR		TR		MR		BE		BR		LMR		MRLL		HRLL		QA	
Overall Rating	**Totals**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
1- Overall Rating	2115	42	37	546	42	279	37	9	12	335	35	196	24	292	32	100	28	138	33	62	21	62	19	53	16	1	7
2 - Overall Rating	3281	48	42	536	41	300	40	57	74	436	45	450	54	500	54	206	58	221	53	178	60	178	54	162	49	9	64
3 - Overall Rating	1141	18	16	180	14	160	21	11	14	156	16	152	18	118	13	40	11	54	13	53	18	85	26	110	33	4	29
4 - Overall Rating	126	5	4	27	2	8	1	0	0	24	2	26	3	9	1	4	1	4	1	6	2	6	2	7	2	0	0
5 - Overall Rating	26	0	0	4	0	0	0	0	0	13	1	2	0	1	0	3	1	2	0	0	0	1	0	0	0	0	0
MH's Inspected	**6,689**	**113**		**1293**		**747**		**77**		**964**		**826**		**920**		**353**		**419**		**299**		**332**		**332**		**14**	

Table 7.2.2.2 - Manhole MACP Condition Ratings 4 & 5

		Herring Run Sub-Sewershed – Manhole Condition Ratings (4 and 5)																									
		HRWB		UHR		HR		LHR		CR		TR		MR		BE		BR		LMR		MRLL		HRLL		QA	
Overall Rating	**Totals**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
4 - Overall Rating	126	5	4	27	2	8	1	0	0	24	2	26	3	9	1	4	1	4	1	6	2	6	2	7	2	0	0
5 - Overall Rating	26	0	0	4	0	0	0	0	0	13	1	2	0	1	0	3	1	2	0	0	0	1	0	0	0	0	0
MH's w/ 4/5 Rating Inspected	**152**	**5**		**31**		**8**		**0**		**37**		**28**		**10**		**7**		**6**		**6**		**7**		**7**		**0**	

Proposed Sanitary Sewer Improvements:
Table 7.2.2.3 shows the length of the sanitary sewers located within the Herring Run Sewershed that were ranked as First and/or Second Priority assets requiring repair and any defects recommended for repair, regardless of overall rating. All First and Second Priority sewers are recommended for repairs. These sewers are further divided into sub-sewersheds for contract scheduling.

Table 7.2.2.3 - Sanitary Sewers in the Herring Run Sewershed

		Herring Run Subsewershed - Sanitary Sewer Condition Ratings (4 & 5)																									
		HRWB		UHR		HR		LHR		CR		TR		MR		BE		BR		LMR		MRLL		HRLL		QA	
Overall Rating	**Totals**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**	**LF**	**%**
1- Overall Rating	208,355	4,003	18	45,767	24	29,186	26	576	69	30,718	17	32,180	21	28,481	20	8,824	15	16,183	25	4,563	16	6,342	14	1,045	2	486	23
2 - Overall Rating	24,807	345	2	3,439	2	2,948	3	-	-	1,659	1	3,825	3	5,243	4	789	1	2,046	3	1,942	7	195	0	2,375	4	-	-
3 - Overall Rating	7,210	-	-	1,856	1	549	0	-	-	725	0	850	1	1,586	1	456	1	-	-	236	1	-	-	951	2	-	-
4/5 Overall Rating	6,329	2,345	11	1,036	1	384	0	-	-	306	0	396	0	878	1	-	-	219	0		-	-	-	767	1	-	-
Total LF:	**246,702**	**6,693**		**52,098**		**33,067**		**576**		**33,408**		**37,250**		**36,188**		**10,070**		**18,448**		**6,741**		**6,538**		**5,138**		**486**	

7.2.3 Proposed Herring Run Collection System Hydraulic Improvements

The Chinquapin Run, Tiffany Run, Herring Run West Branch, Upper Herring Run, Herring Run, Lower Herring Run and Moore's Run sub-sewersheds require hydraulic improvements to reduce sanitary sewer overflows when conveying wet-weather events. Map 7.2.3 details the locations of the following projects described on a sub-sewershed basis.

Chinquapin Run
It is recommended that the abandoned 21-inch diameter sewer, which connected the Chinquapin Run Interceptor to the Herring Run Interceptor, be reinstated (reference Figure 5.4.1.) and that a 0.6 MG storage facility be constructed at some location along Northwood Drive between The Alameda and Woodbourne Avenue to attenuate wet-weather peak flows. Additionally, it is recommended that CIPP lining be installed in all sewers and that all manholes be lined in sub-catchment 33-17-01-00 and that manhole S45QQ1008MH be sealed to eliminate SSO at this lower-elevation location.

Tiffany Run
It is recommended to CIPP line all of the pipes and rehabilitate all of the manholes in four of the sub-catchments (identified as 33-11-02-02A, B, C and D) located in the southern section of the Tiffany Run sub-sewershed. To eliminate overflows near Lake Montebello, it is recommended that the sewer system be reconfigured by constructing a new 10-inch diameter sewer under Hillen Road (reference Figure 5.4.2).

Herring Run, West Branch
A parallel 15-inch diameter relief sewer from the City/County line to a 20-inch diameter sewer segment of the Herring Run West Branch interceptor is recommended to convey County flows.

Upper Herring Run
Approximately 1,500 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer and approximately 1,500 LF of 12-inch diameter sewer is recommended to be replaced with 15-inch diameter sewer. Additionally, five manholes (S51UU1008MH, S51UU1012MH, S51UU1013MH, S51UU1016MH and S51UU1017MH) are recommended to be sealed to prevent SSOs at these lower-elevation locations.

Herring Run
A 3.0 MG offline storage facility is recommended to attenuate peak wet-weather flows and manholes SS7UU_005MH and SS7UU_00MH7 are recommended to be sealed to prevent SSOs at these lower-elevation locations.

Moore's Run
Approximately 800 LF of 10-inch diameter sewer is recommended to be replaced with 12-inch diameter sewer to convey peak wet-weather flows

7.3 Proposed Improvement Implementation Schedule

An implementation schedule for completion of the proposed SSO elimination and sewer system improvements has been developed as part of this project based on project cost, anticipated project duration, available manpower, and materials. In all cases, projects have been scheduled to minimize public impact and coordinated with other similar projects being conducted throughout the City. The implementation schedule was developed with consideration that all proposed improvements must be completed before January 1, 2016 as stipulated by the CD. The following schedules have been developed providing time to successfully complete the required work.

Sanitary Sewer Overflows:
The newly discovered SSO 137 can be eliminated utilizing the City's maintenance division without outside contracting; therefore, engineering and contractor procurement will not be necessary. A reasonable duration to eliminate this overflow would be by January 1, 2011.

Manhole Rehabilitation:
The schedule provided in Table 7.3.1 represents a reasonable duration required for the City to select an engineering consultant to prepare the required design documents, advertise the project, select a contractor to complete the required repairs and have the effectiveness of the repairs evaluated.

Table 7.3.1 - Manhole Rehabilitation Implementation Schedule

Paragraph 9 Project ID	Project Title	Project Description	CD Milestone Dates		
			Advertise Project	Construction Complete	Evaluation Phase Completion
9	Sanitary Sewer Manhole Rehabilitation	Completion of Manhole Rehabilitation/Replacement Projects Throughout the Herring Run Sewershed	12/1/2012	6/1/2013	5/1/2014

Sanitary Sewer Rehabilitation:
The schedule provided in Table 7.3.2 represents a reasonable duration required for the City to select an engineering consultant to complete the required design documents, advertise the project, select a contractor to complete the work and have the effectiveness evaluated.

Table 7.3.2 - Sanitary Sewer Rehabilitation Implementation Schedule (First & Second Priority)

Paragraph 9 Project ID	Project Title	Project Description	CD Milestone Dates		
			Advertise Project	Construction Complete	Evaluation Phase Completion
10	First Priority Rehabilitation	CIPP, Point Repairs, and Combination CIPP/Point Repairs for First Priority	7/1/2012	1/1/2013	1/1/2014
10A	Second Priority Rehabilitation	CIPP, Point Repairs, and Combination CIPP/Point Repairs for Second Priority	7/1/2012	10/1/2014	10/1/2015

Hydraulic Improvements:
The schedule provided in Table 7.3.3 represents a reasonable duration for the City to select an engineering consultant to complete the required design documents, advertise the project, select a contractor, implement the required improvements and evaluate the effectiveness of the repairs.

Table 7.3.3 - Hydraulic Improvement Schedule

Paragraph 9 Project ID	Project Title	Project Description	CD Milestone Dates		
			Advertise Project	Construction Complete	Evaluation Phase Completion
11	Chinquapin Run I/I Reduction & Rehabilitation	CIPP Lining 8- to 24-Inch Sewers and Manhole Lining and Replacement	6/1/2012	11/1/2012	12/1/2014
12	Chinquapin Run Storage Tank	0.6 MG Wastewater Storage Tank	5/1/2013	9/1/2014	9/1/2015
13	Tiffany Run I/I Reduction & Rehabilitation	CIPP Lining 8- to 12-Inch Sewers and Manhole Lining and Replacement	6/1/2012	2/1/2013	2/1/2014
14	Tiffany Run Sewer Replacement	Miscellaneous 10-Inch Sewer Replacement	12/1/2012	4/1/2013	4/1/2014
15	Herring Run West Branch Parallel Sewer	Herring Run West Branch 15-Inch Parallel Sewer	4/1/2013	8/1/2013	8/1/2014
16	Upper Herring Run Sewer Replacement	Miscellaneous 10 and 12-Inch Sewer Replacement	8/1/2012	8/1/2014	1/1/2014
17	Herring Run Storage Tank	3.5 MG Wastewater Storage Tank	1/1/2013	5/1/2015	1/1/2016
18	Lower Hering Run	Miscellaneous Manhole Rehabilitation	On-Call Contract		
19	Moore's Run Sewer Replacement	Miscellaneous 10-Inch Sewer Replacement	8/1/2012	8/1/2013	8/1/2015

7.4 Estimated Costs of the Proposed Improvement Projects

To characterize expected costs for the collection system improvements necessary in the Herring Run Sewershed, the City completed a review of information compiled from prior City projects for various types of repairs, rehabilitation and replacement of manholes and sanitary sewers. In addition costs were also collected from Means' and a national study of unit costs for a wide variety of repair/replacement options in locations throughout the United States. Once compiled, the information was reviewed, compared and normalized for use in preparing reasonable estimates for the City's sewershed improvements.

The unit prices developed by the City represent average unit costs that were derived from the sources identified. There was however, some significant variability noted when comparing the unit costs developed by contractors bidding on the same project, and there was considerable variability when comparing these documented unit costs with other similar types of repair techniques employed on different projects. Such unit cost variability reflects both the site specific nature of each project as well as the normal variability typically associated with varying markets, project time constraints and other construction related considerations. While it is understood that site specific attributes will have an impact on final costs for a given rehabilitation/repair/replacement effort, it is the City's intent to ensure that all of the sewersheds use the same baseline cost assumptions for consistency and planning purposes. These fully-loaded costs are an attempt to capture all the relevant costs associated with a construction project such as mobilization, bypass pumping, site/paving restoration, and repair of other utilities, which can add significantly to the cost, but are typically required to complete the overall project.

7.4.1 Estimated Improvement Budget

The following section outlines the proposed costs utilizing fully-loaded cost data required to implement the First and Second Priority collection system improvements.

Estimated Manhole Rehabilitation Budget:
Table 7.4.1 is the estimated 2008 costs required to rehabilitate all First and Second Priority sanitary sewer manholes identified in the Herring Run collection system.

Table 7.4.1 - Estimated Manhole Rehabilitation and Replacement Improvement Budget

First Priority Manholes				
Item	**Method**	**Unit Cost**	**Quantity (ea.)**	**Cost**
Manhole	Rehabilitation/Replacement	$3,719	126	$468,594
Design, Const. Mngt./Insp. Etc. (42%):				$196,809
Total - First Priority MH's				$665,403
Second Priority Manholes				
Manhole	Rehabilitation/Replacement	$3,719	26	$96,694
Estimated Design, Const. Mngt./Insp. Etc. (42%):				$40,611
Total - Second Priority MH's				$137,305
Total Estimated First and Second Priority Manholes:				**$802,709**

Estimated Sanitary Sewer Rehabilitation Budget:
Table 7.4.2 is the estimated 2008 costs required to rehabilitate all First and Second Priority sanitary sewers identified in the Herring Run collection system.

Table 7.4.2 - Estimated Sewer Rehabilitation and Replacement Improvement Budget

First Priority Sewers					
Sewer Size	**Unit Cost (s)**		**Quantity (LF)**		**Cost**
CIPP Lining					
8" Sewer Lining:	$45		669		$30,105
8+" - 12" Sewer Lining:	$64		2,026		$129,664
12+" - 18" Sewer Lining:	$87		1,718		$149,466
18+" - 24" Sewer Lining:	$124		4045		$501,580
24+" - 30" Sewer Lining:	$169		3846		$649,974
30+" - 36" Sewer Lining:	$186		1872		$348,192
Total CIPP Lining:			14,176		$1,808,981
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$759,772
Total First Priority CIPP Lining:					$2,568,753
Point Repairs (assume 10' repair)					
8" Point Repair:	$378		10		$3,780
8+" - 12" Point Repairs:	$378		90		$34,020
12+" - 18" Point Repairs:	$378		10		$3,780
18+" - 24" Point Repairs:	$672		20		$13,440
24+" - 30" Point Repairs:	$841		30		$25,230
Total Point Repairs:			160		$80,250
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$33,705
Total First Priority Spot Repairs:					$113,955
Point Repair & CIPP Lining					
	Point Repair	CIPP	Point Repair	CIPP	
8" Point Repair/CIPP:	$378	$45	0	0	$0
8+" - 12" Point Repairs/CIPP:	$378	$64	0	0	$0
12+" - 18" Point Repairs/CIPP:	$378	$87	0	0	$0
18+" - 24" Point Repairs/CIPP:	$841	$124	0	0	$0
Total Point/CIPP Repairs:			0	0	$0
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$0
Total First Priority Point/CIPP Repairs:					$0
Replacement (assume > 10' repair)					
8" Replacement:	$270		18		$4,860
8+" - 12" Replacement:	$495		63		$31,185
12+" - 18" Replacement:	$585		177		$103,545
18+" - 24" Replacement:	$1,080		0		$0
24+" - 30" Replacement:	$1,440		0		$0
Total Replacements:			258		$139,590
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$58,628
Total First PriorityReplacement Repairs:					$198,218
Replacement & CIPP Lining					
	Replacement	CIPP	Replacement	CIPP	
8" Replacement/CIPP:	$270	$45	0	0	$0
8+" - 12" Replacement/CIPP:	$495	$64	0	0	$0
12+" - 18" Replacement/CIPP:	$585	$87	0	0	$0
18+" - 24" Replacement/CIPP:	$1,060	$124	0	0	$0
Total Replacement/CIPP Repairs:			0	0	$0
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$0
Total First Priority Replacement Repairs:					$0
Total Estimated First Priority Sewers:					**$2,880,926**

Second Priority Sewers					
Sewer Size	**Unit Cost (s)**		**Quantity (LF)**		**Cost**
CIPP Lining					
8" Sewer Lining:	$45		60,881		$2,739,645
8+" - 12" Sewer Lining:	$64		5,257		$336,448
12+" - 18" Sewer Lining:	$87		762		$66,294
18+" - 24" Sewer Lining:	$124		401		$49,724
24+" - 30" Sewer Lining:	$169		0		$0
30+" - 36" Sewer Lining:	$186		779		$144,894
Total CIPP Lining:			68,080		$3,337,005
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$1,401,542
Total Second Priority CIPP Lining:					$4,738,547
Point Repairs (assume 10' repair)					
8" Point Repair:	$378		0	8,290	$3,133,620
8+" - 12" Point Repairs:	$378		0	250	$94,500
12+" - 18" Point Repairs:	$378		0	40	$15,120
18+" - 24" Point Repairs:	$672		0	10	$6,720
24+" - 30" Point Repairs:	$841		0	-	$0
Total Point Repairs:			0	8,590	$3,249,960
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$1,364,983
Total Second Priority Spot Repairs:					$4,614,943
Point Repair & CIPP Lining					
	Point Repair	CIPP	Point Repair	CIPP	
8" Point Repair/CIPP:	$378	$ 45	460	10,174	$631,710
8+" - 12" Point Repairs/CIPP:	$378	$ 64	30	408	$37,452
12+" - 18" Point Repairs/CIPP:	$378	$ 87	0	0	$0
18+" - 24" Point Repairs/CIPP:	$672	$ 124	0	0	$0
24+" - 30" Point Repairs/CIPP:	$841	$ 169	0	0	$0
30+" - 36" Point Repairs/CIPP:	$988	$ 186	0	0	$0
36+" - 42" Point Repairs/CIPP:	$1,008	$ 330	10	851	$290,910
Total Point/CIPP Repairs:			500	11433	$960,072
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$403,230
Total Second Priority Point/CIPP Repairs:					$1,363,302
Replacement (assume > 10' repair)					
8" Replacement:	$270		5,828		$1,573,560
8+" - 12" Replacement:	$495		991		$490,545
12+" - 18" Replacement:	$585		15		$8,775
18+" - 24" Replacement:	$1,060		0		$0
Total Replacements:			6,834		$2,072,880
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$870,610
Total Second PriorityReplacement Repairs:					$2,943,490
Replacement & CIPP Lining					
	Replacement	CIPP	Replacement	CIPP	
8" Replacement/CIPP:	$270	$45	76	408	$38,880
8+" - 12" Replacement/CIPP:	$495	$64	-	-	$0
12+" - 18" Replacement/CIPP:	$585	$87	-	-	$0
18+" - 24" Replacement/CIPP:	$1,060	$124	-	-	$0
Total Replacement/CIPP Repairs:			76	408	$38,880
Estimated Design, Const. Mngt./Insp. Etc. (42%):					$16,330
Total Second Priority Replacement Repairs:					$55,210
Total Estimated Second Priority Sewers:					**$13,715,492**
Total Estimated First and Second Priority Sewers:					**$16,596,418**

Estimated Hydraulic Improvement Budget:
Table 7.4.3 contains the estimated 2008 costs required to complete the hydraulic improvements for each sub-sewershed in the Herring Run Sewershed.

Table 7.4.3 - Estimated Hydraulic Improvement Budget

Diameter	Rehabilitation Method	Unit Cost	Quantity	Cost
Chinquapin Run Sub-Sewershed				
Equalization Tank	Storage	$6 /Gal	600,000	$3,600,000
10-Inch Pipe	CIPP Lining	$64 /LF	210	$13,440
18-Inch Pipe	New	$585 /LF	66	$38,610
21-Inch Pipe	CIPP Lining	$124 /LF	1,543	$191,332
21-Inch Pipe	New	$1,080 /LF	513	$554,040
27-Inch Pipe	CIPP Lining	$169 /LF	592	$100,048
30-Inch Pipe	CIPP Lining	$169 /LF	655	$110,695
Manholes	Rehabilitate	$3,719 /EA	22	$81,818
			Subtotal:	$4,689,983
			Estimated Design, Const. Mngt./Insp. Etc. (42%):	$1,969,793
			Total:	**$6,659,776**
Tiffany Run Sub-Sewershed				
8-Inch Pipe	CIPP Lining	$45 /LF	9,811	$441,495
10-Inch Pipe	CIPP Lining	$64 /LF	2,386	$152,704
10-Inch Pipe	New	$495 /EA	381	$188,595
12-Inch Pipe	CIPP Lining	$64 /LF	521	$33,344
Manholes	Rehabilitate	$3,719 /LF	37	$137,603
			Subtotal:	$953,741
			Estimated Design, Const. Mngt./Insp. Etc. (42%):	$400,571
			Total:	**$1,354,312**
Herring Run West Branch Sub-Sewershed				
15-Inch Pipe	New	$585 /LF	3,940	$2,304,900
Manholes	New	$3,719 /EA	15	$55,785
			Subtotal:	$2,360,685
			Estimated Design, Const. Mngt./Insp. Etc. (42%):	$991,488
			Total:	**$3,352,173**
Upper Herring Run Sub-Sewershed				
10-Inch Pipe	Replace	$495 /LF	1,471	$728,145
12-Inch Pipe	Replace	$585 /LF	1,500	$877,500
Manholes	New	$3,719 /EA	17	$63,223
			Subtotal:	$1,668,868
			Estimated Design, Const. Mngt./Insp. Etc. (42%):	$700,925
			Total:	**$2,369,793**
Herring Run Sub-Sewershed				
Equalization Tank	Storage	$6 /Gal	3,000,000	$18,000,000
36-Inch Pipe	New	$1,530 /LF	343	$524,790
Manholes	Rehabilitate	$3,719 /EA	2	$7,438
			Subtotal:	$18,532,228
			Estimated Design, Const. Mngt./Insp. Etc. (42%):	$7,783,536
			Total:	**$26,315,764**
Moore's Run Sub-Sewershed				
10-Inch Pipe	Replace	$495 /EA	825	$408,375
Manholes	New	$3,719 /EA	10	$37,190
			Subtotal:	$445,565
			Estimated Design, Const. Mngt./Insp. Etc. (42%):	$187,137
			Total:	**$632,702**
			Total Estimated Hydraulic Improvement Costs:	**$40,684,519**

The combined total costs associated with completing the First and Second Priority manhole repairs, sewer system repairs, and the hydraulic improvements to the conveyance system in the Herring Run Sewershed are estimated to be approximately $58,083,646.

7.5 Sewershed Re-Inspection Program

Per the requirements of the CD, the City's Herring Run Sewershed's collection system needs to be re-inspected by January 1, 2016. The following sections outline the requirements of the re-inspection program and provide a general schedule to complete this work.

7.5.1 Re-Inspection Prioritization Scheme

The City's condition and criticality protocol provides a framework for a continuous rehabilitation strategy of all collection system components based on both criticality (consequence of failure) and condition (probability of failure). Assets whose failure can have large impacts on the community and the environment and whose condition is the poorest will receive a higher criticality and condition rating and will receive attention in a more timely manner. Assets that receive a lower criticality and condition rating will receive some level of continued monitoring as recommended herein but no immediate action or rehabilitation. Refer to Section 7.1 Decision Making Criteria for details. The following sections detail the requirements of future inspection programs.

7.5.2 CCTV and Manhole Inspections

The implementation schedule provided includes provisions for the re-inspection of each of the sub-sewershed collection system components by January 1, 2016. The proposed re-inspection schedule includes provisions for, but is not necessarily limited to, a prioritization scheme for further inspection of collection system components based on the following criteria:

1. Prior identification of system defects, prior NASSCO PACP or MACP rating codes, grease blockages, root intrusion or system complaint data.
2. Prior criticality and condition ratings.
3. Expected life cycle of system components.
4. Estimated rate of existing or potential inflow and/or infiltration.
5. Scheduled rehabilitation or other corrective action of a system component; and the predetermined re-inspection frequency of a collection system component.

Current sewershed studies are scheduled to be completed between June 2009 and July 2010. Following these studies, the City intends to implement a continuous CCTV and manhole inspection program aimed at re-inspecting all gravity sewers 8-inches and larger, and all force mains, pumping stations, manholes and other sewer structures by January 1, 2016. The planned re-inspection activities will be prioritized based on the condition and criticality factors determined during this project.

The implementation schedule for re-inspection of these sewershed system components is outlined in Table 7.5.1:

Table 7.5.1 - Sewershed Re-Inspection Implementation Schedule

Task	Duration (Mos.)	Start Date	End Date	2011	2012	2013	2014	2015	2016
Manhole Inspections	30	5/1/2012	11/1/2014						1-Jan-16
Analysis and Report	33	6/1/2012	5/1/2015						
Pumping Station Insp.	1	6/1/2014	7/1/2014						
Analysis and Report	1	7/1/2014	8/1/2014						
Force Main Inspections	1	6/1/2014	7/1/2014						
Analysis and Report	1	7/1/2014	8/1/2014						
Sewer Inspections	25	5/1/2012	6/1/2014						
Analysis and Report	28	7/1/012	11/1/2014						

Based on the condition of the assets observed during this study, manholes and sewers that received higher condition and criticality rating scores were recommended for inclusion on the First and Second Priority corrective action plan. Once rehabilitated, these manholes and sewers can be placed on a "Low Priority" inspection program with regular inspections occurring once every 5 to 10 years. The manholes and sewers that received condition ratings of 3 were classified as requiring "Frequent Assessment" under the condition and criticality rating system can be inspected on regular 2-3 year inspection intervals to insure the continuity of the collection system. Manholes and sewer segments that are currently in serviceable condition but received higher criticality ratings were identified as requiring "Regular Monitoring" and can be inspected every 3-5 years. Based on the results of those inspections, any manholes and/or sewers that have continued to deteriorate to a point that requires repair should be repaired on an as-needed basis to address specific problems or deficiencies that have occurred.

7.6 Future Data Collection and Evaluation Services

As required by the CD, under Paragraph 9-C-xii, the City will be required to implement several continuous data collection programs in order to assess the effectiveness of the rehabilitation programs and other O&M enhancement efforts within the sewershed. These programs will be comprehensive, system-wide initiatives that will include a long-term flow monitoring plan, a sewer cleaning program, CCTV and manhole inspection programs and root control and grease control programs. These are discussed in more detail in the following sections.

7.6.1 Long-Term Flow Monitoring Plan

In 2006, under Project 935, the City of Baltimore implemented a comprehensive flow monitoring program for the purpose of evaluating the severity of infiltration and inflow and for calibration of the hydraulic model. This comprehensive program consisted of a network of about 350 flow meters, 20 rain gauges, 33 groundwater monitoring stations and extended for a period of one year from May 2006 through May 2007. In May 2007, the network was reduced to about 100 flow meters that were placed at key points and junctions in the collection system for the purpose of long term assessment and continuous calibration of the hydraulic model. All 20 rain gauges remained in operation. The City plans to continue monitoring the flows in order to assess the effectiveness of the on-going and future rehabilitation and O&M enhancement programs.

7.6.2 Sewer Cleaning Program

The effectiveness of a sewer conveyance system is largely dependent on its ability to convey the flows generated within the sewer basin without surcharging the system to a point where overflows occur. As part of the sewer inspection program completed for this study, all sewers that were inspected were also cleaned. The intent of the cleaning was to clean the sewer so the inspections could identify defects that otherwise would not be visible during the inspection and to remove debris from the sewer to restore the sewer to at least 95% of its original carrying capacity. When significant restrictions such as roots or other debris was encountered, heavy cleaning was utilized to restore the capacity of the sewers and allow for internal inspection. Heavy cleaning involved root cutting, grease removal and/or additional passes of the hydro-cleaning equipment to remove heavy accumulations of sediment and debris. All debris was removed from the sewers and disposed of at an approved disposal site.

Based on the cleaning work completed during this project and observations from the inspection work completed, it is recommended that sewers which contain heavy accumulations of grease, debris and/or roots, large interceptor sewers, sewer siphons, and sewers should be cleaned on a regular basis to maintain adequate hydraulic capacity. These cleaning operations should be closely coordinated with the sewer re-inspection program, which needs to be completed by January 1, 2016 and prioritized based on condition and criticality rating factors that were determined during the inspections described in Section 7.1. Under normal operating conditions, the remaining sewers should require less frequent cleaning.

7.6.3 CCTV and Manhole Inspection Programs

The City also intends to implement continuous citywide CCTV and manhole inspection programs following the completion of the CD sewershed studies, which are scheduled to be completed between June 2009 and July 2010. These programs will be aimed at re-inspecting all gravity sewers 8-inches and larger in diameter, force mains, pumping stations, manholes and other sewer structures by January 1, 2016. The planned re-inspection activities will be prioritized based on each segment's condition and criticality ratings that were derived during the sewershed inspections described in Section 7.1 of this report.

In accordance with City guidelines, all PACP condition grade 1 and 2 sewers in the Herring Run Sewershed should be re-inspected in a 5 to 10 year range. All PACP condition grade 3 sewers should be re-inspected in 2 to 3 years to reassess their condition and assign appropriate repairs as needed.

7.6.4 Root Control Program

In 2004, under Project 1015, the City began monitoring the impacts of root infestation in their collection system by tracking and geocoding customer calls related to root problems in the sewer. In 2006, the City identified an area in the Herring Run Sewershed having severe root intrusion problems (approximately 1,500 acres, 230,000 linear feet of pipe). The City proceeded to implement a root control chemical application pilot project in this area in 2007, which included the treatment of approximately 150 house laterals and service connections. The pilot project yielded promising results. The City is therefore expanding the Root Control Program (RCP) into other areas of the collection system with documented root intrusion problems. A recent evaluation of customer calls in 2007 identified two additional areas with severe root infestation (see Figure 7.6.1).

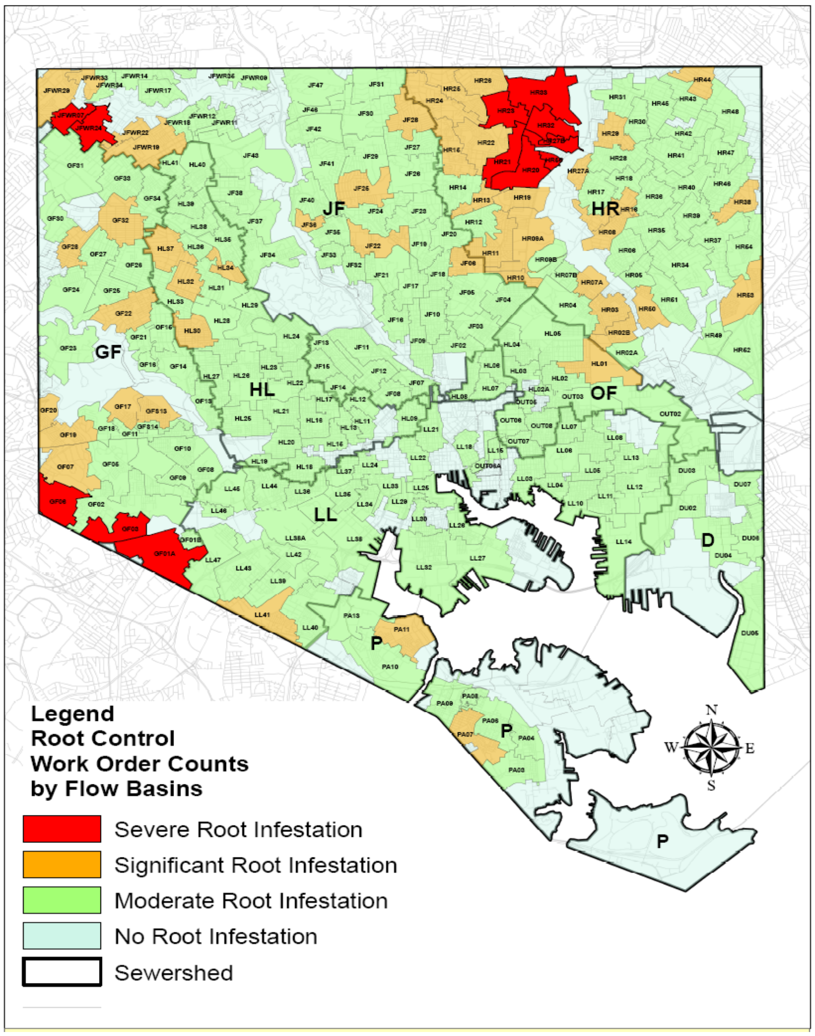


Figure 7.6.1 – Root Control Analysis

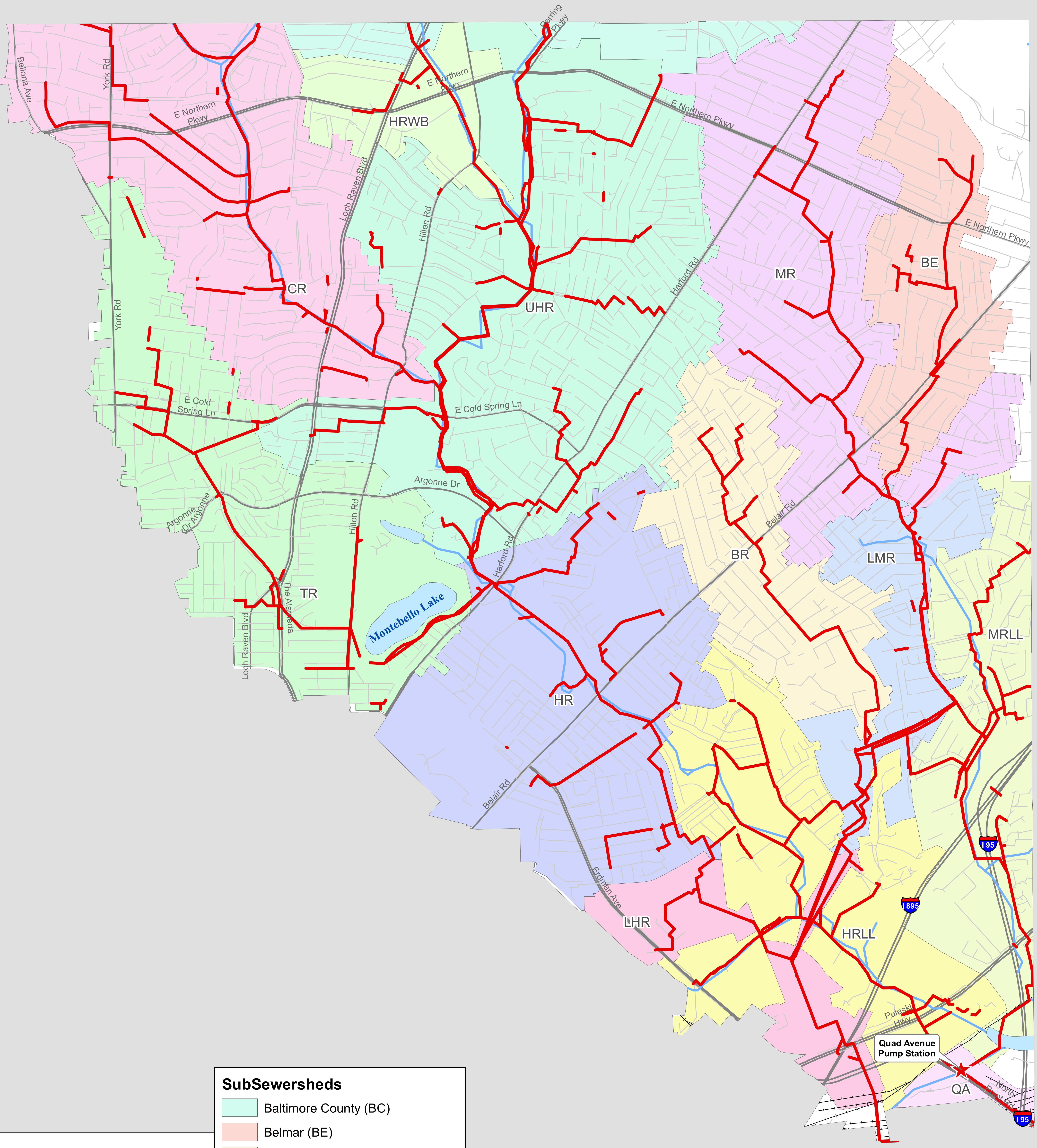
To evaluate the effectiveness of the on-going root control program, the Project 1015 Technical Manager will use other sources of information, such as CCTV and manhole inspections, will be used to validate and direct the root control efforts. The goal of the on-going RCP is to treat all areas of the collection system experiencing root infestation once every three to five years. The effectiveness of the RCP will be assessed by continued monitoring of the areas and continuous evaluation of customer complaint calls within these areas on a six month review basis.

7.6.5 Fats, Oils and Grease Control Programs

Similar to root infestation in the sewer system, the City, under Project 1015, began assessing the impacts of Fats, Oils and Grease (FOG) in the collection system in 2004. The City geocoded and mapped all customer complaint calls related to FOG and identified five sections of the collection system where severe problems exist. Not surprisingly, these sections serve areas with numerous restaurants and/or food establishments, namely Little Italy and the Johns Hopkins Hospital area - where many restaurants serve the hospital community, and the upper reaches of the High Level Sewershed, which have numerous restaurants and a major mall with a food court. The City proceeded to outfit two of its newest sewer vac-trucks with de-greasing equipment and began treating the targeted areas in 2006. These areas are currently on a regular cleaning schedule and are addressed twice a year for grease. Baltimore will continue to evaluate customer complaint calls and utilize CCTV and manhole inspection data in order to assess and guide future activities of the FOG Program.

7.6.6 Re-Inspection Prioritization Scheme

The condition and criticality protocol provides a framework for a continuous rehabilitation strategy of all collection system components based on both criticality (consequence of failure) and condition (probability of failure). Assets whose failure can have large impacts on the community and/or the environment and whose condition is the poorest will be a priority and receive attention sooner. Refer to Section 7.1 Decision Making Criteria – Condition and Criticality Assessment for details.



Legend
Pump Stations
Interceptors
Other Sewers
Major Roads
Railroads
Streams
Water

SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Map 1.4.1

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Major Sewers and Pump Stations

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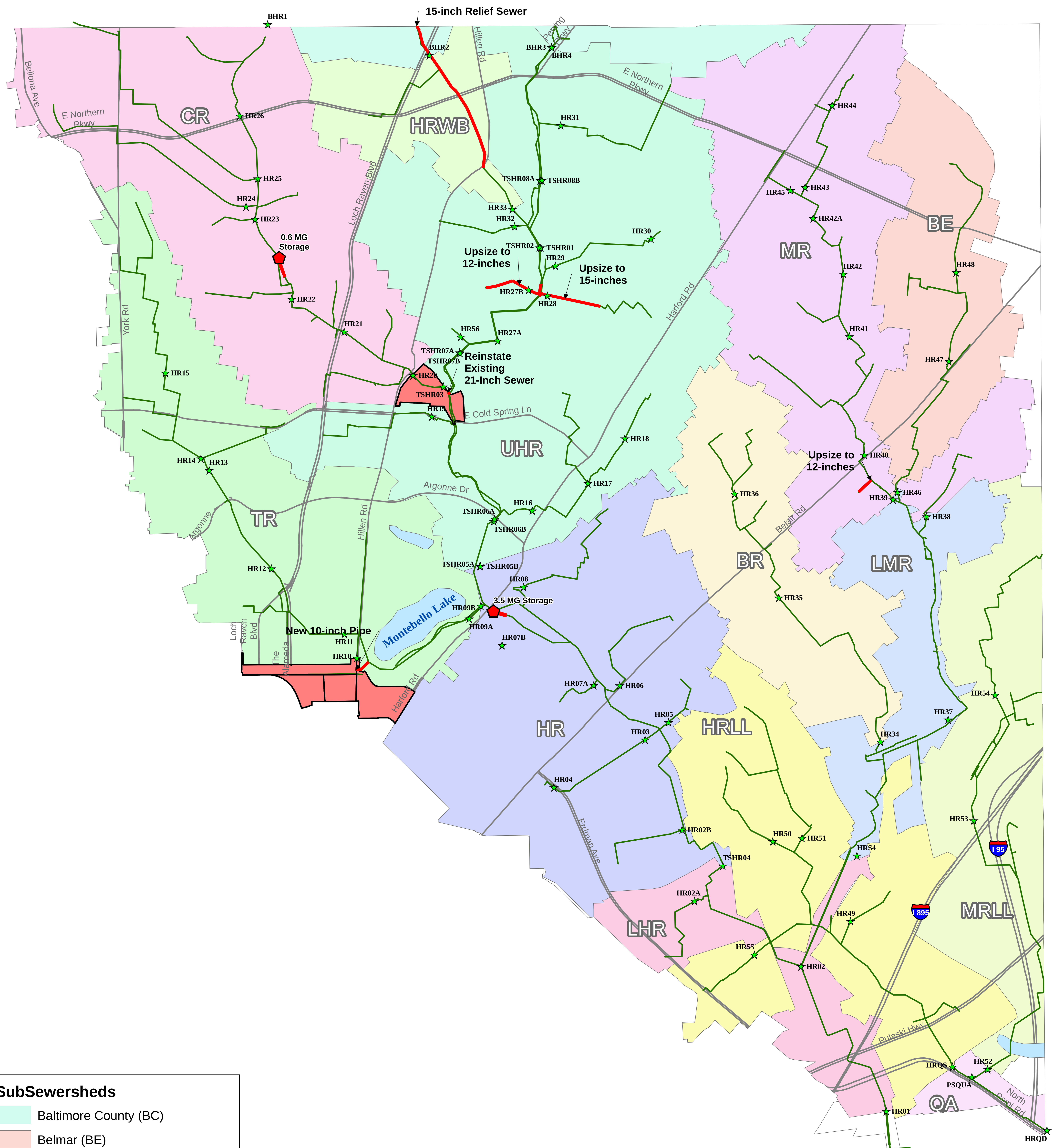
March 21, 2009

Scale: 1 inch equals 0.25 miles

MajorSewers.mxd J.Steurer 3/21/2009



SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Legend

- Storage Tank
- Flowmeter
- Proposed Pipe Upgrade
- All Sewers and Manholes to be Rehabilitated in This Area
- HerringRunMask

Map 2.0.1

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Alternative Analysis (2-year Storm)

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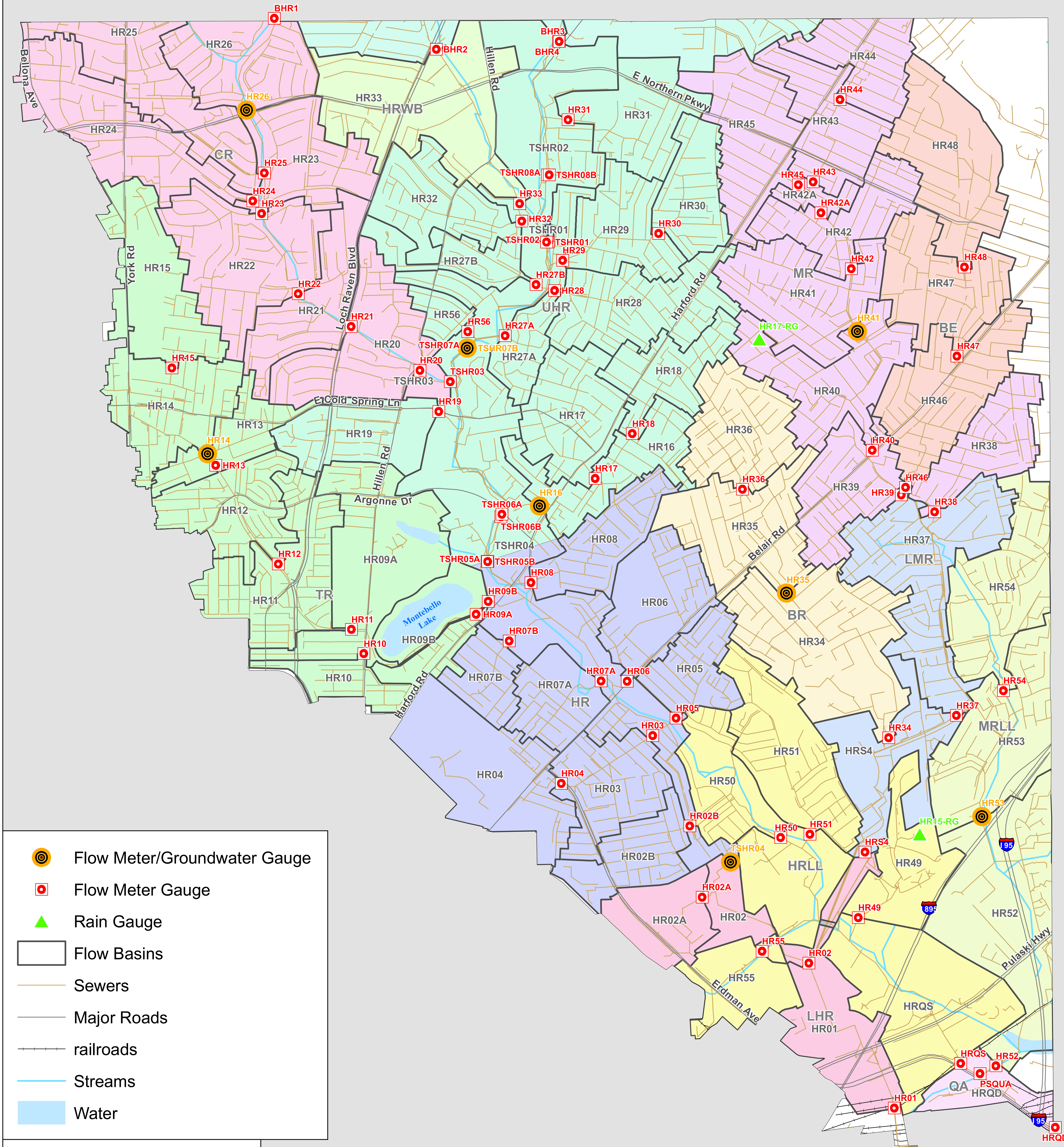
June 23, 2009

Scale: 1 inch = 0.25 miles

Improvements2year.mxd A. Black 6/23/2009



- Flow Meter/Groundwater Gauge
- Flow Meter Gauge
- Rain Gauge
- Flow Basins
- Sewers
- Major Roads
- railroads
- Streams
- Water

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Additional Nearby Rain Gauges:

* JF12-RG - 507 W. Preston St. - Samuel Coleridge-Taylor Elementary
* JF13-RG - 5207 Roland Ave. - Roland Park Elementary
* JF14-RG - 69 Cedar Ave. - Towson High School
* HR16-RG - 428 Westham Way - Eastwood Center Elementary
* HR19-RG - 8300 Pleasant Plains Rd. - Pleasant Plains Elementary
* DU04-RG - 2203 Broening Hwy. - Dundalk Pump Station

Map 3.2.1

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Flow Monitoring and Rain Gauge Network

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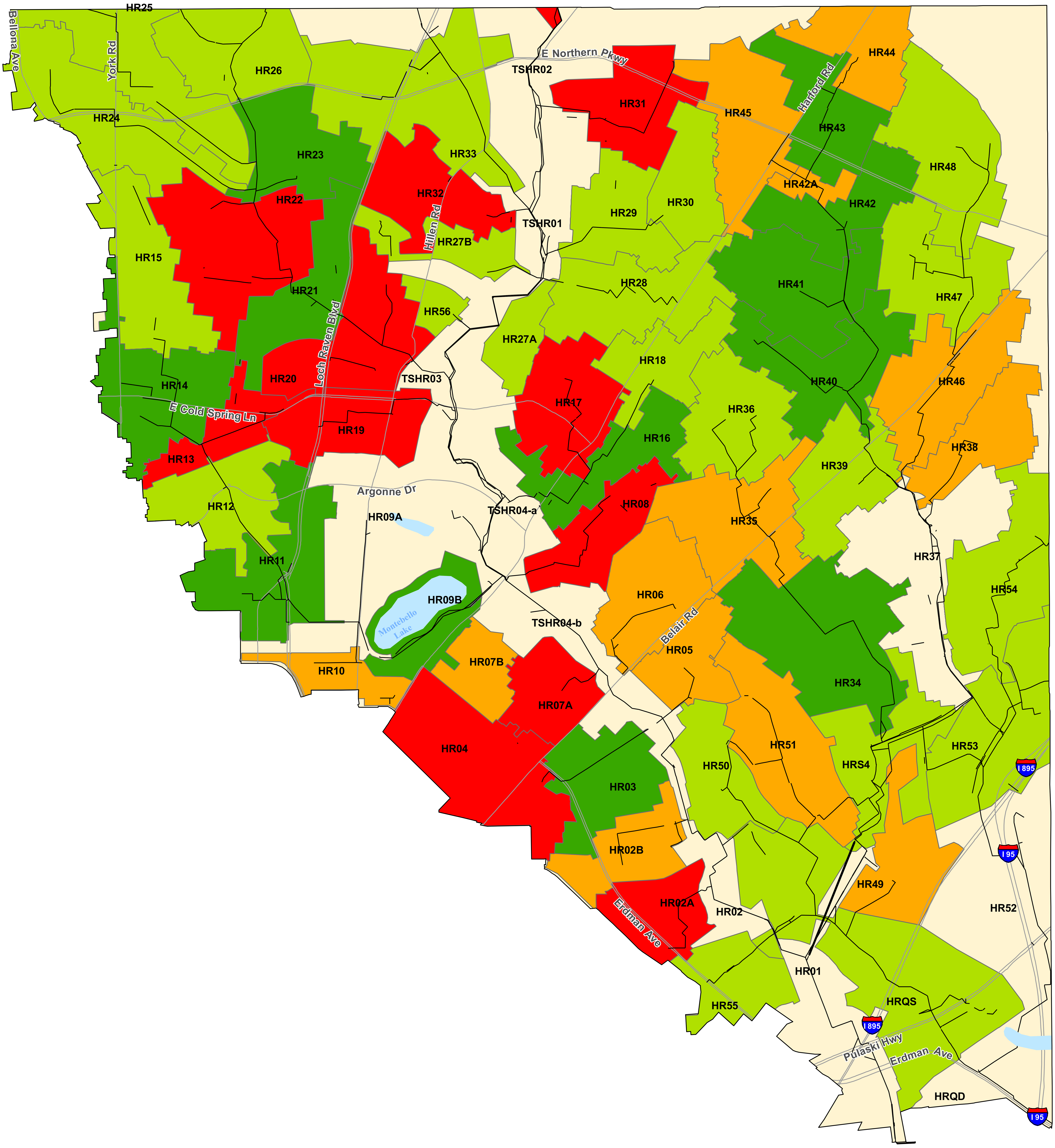
Scale: 1 inch equals 0.25 miles



Avg. Daily Infiltration by Flow Basin (gallons/IDM)

- Not included in analysis
- 0-1,999
- 2,000-3,999
- 4,000-5,999
- >6,000
- Sewers

Map 3.6.1

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Base Infiltration Severity

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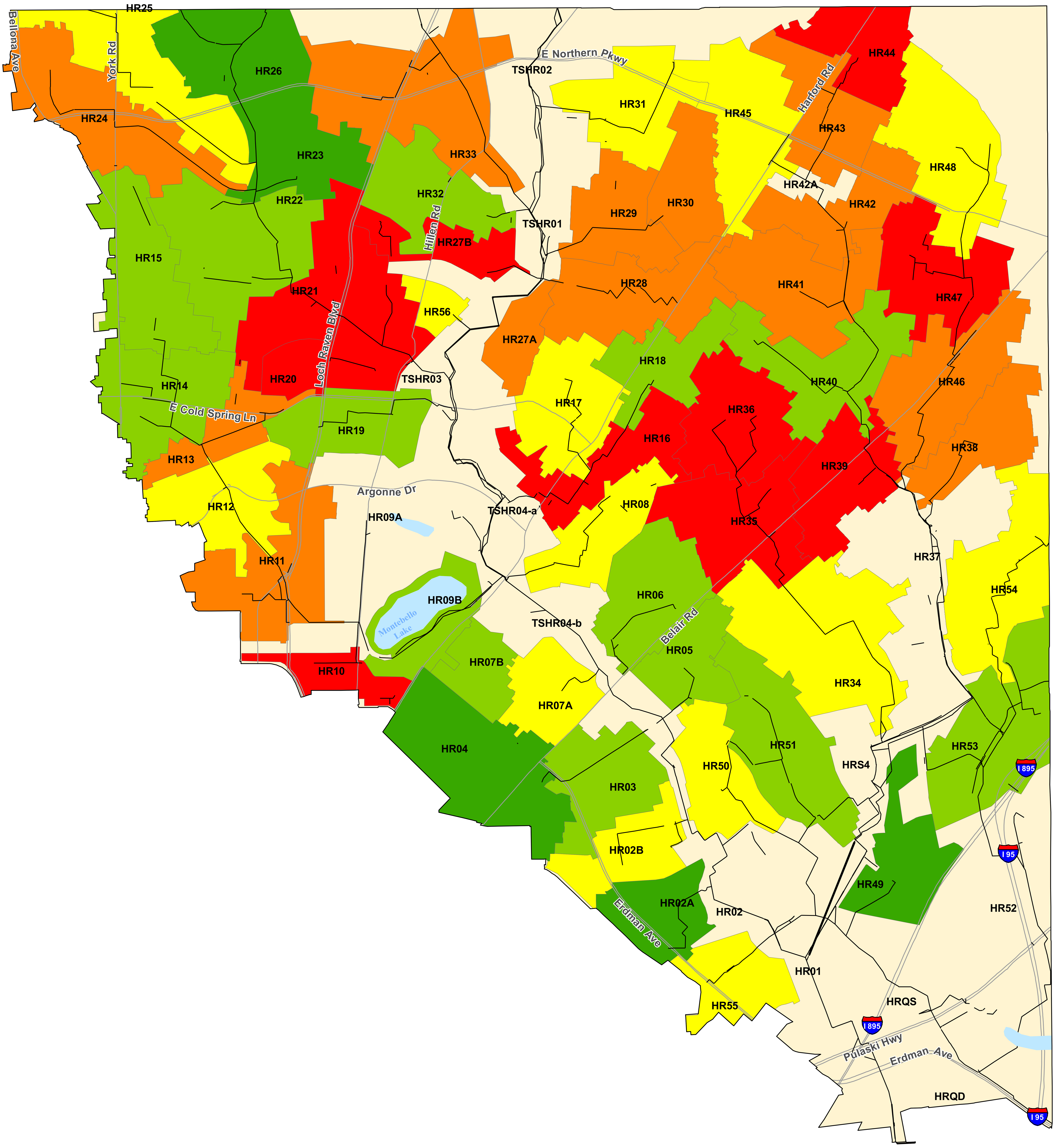
March 22, 2009

Scale: 1 inch equals 0.25 miles

BaseInfiltration.mxd J.Steurer 3/22/2009



"R" Value by Flow Basin

- Not included in analysis
- 0-2%
- 2-4%
- 4-6%
- 6-10%
- >10%
- Sewers

Map 3.7.1

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed RDII Severity

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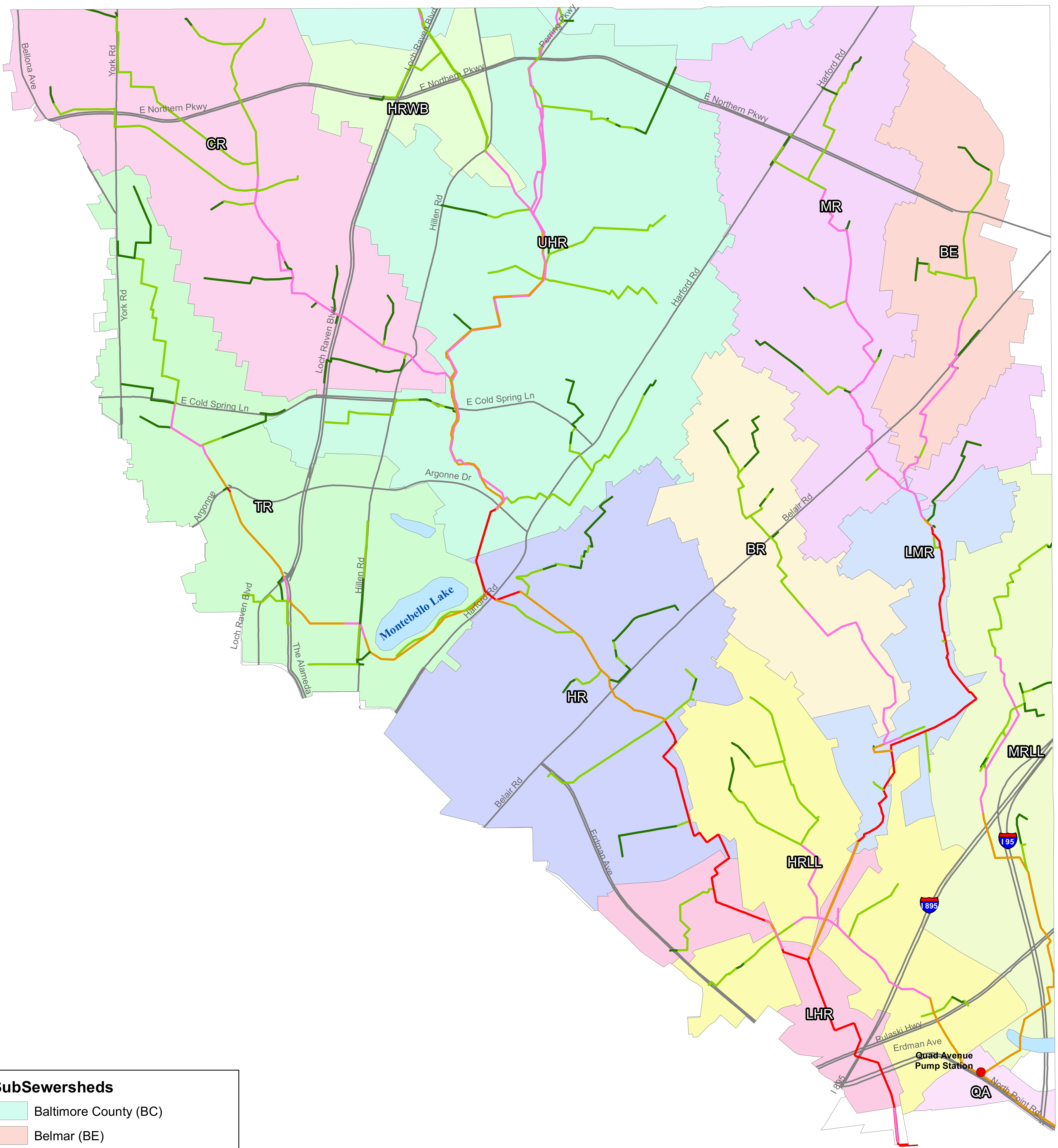
March 22, 2009

Scale: 1 inch equals 0.25 miles

RDII.mxd J.Steurer 3/22/2009



SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Modeled Pipes

Diameter

- <=10"
- 12-18"
- 20-29"
- 30-38"
- >=42"

N

Map 5.1.1

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Model Network

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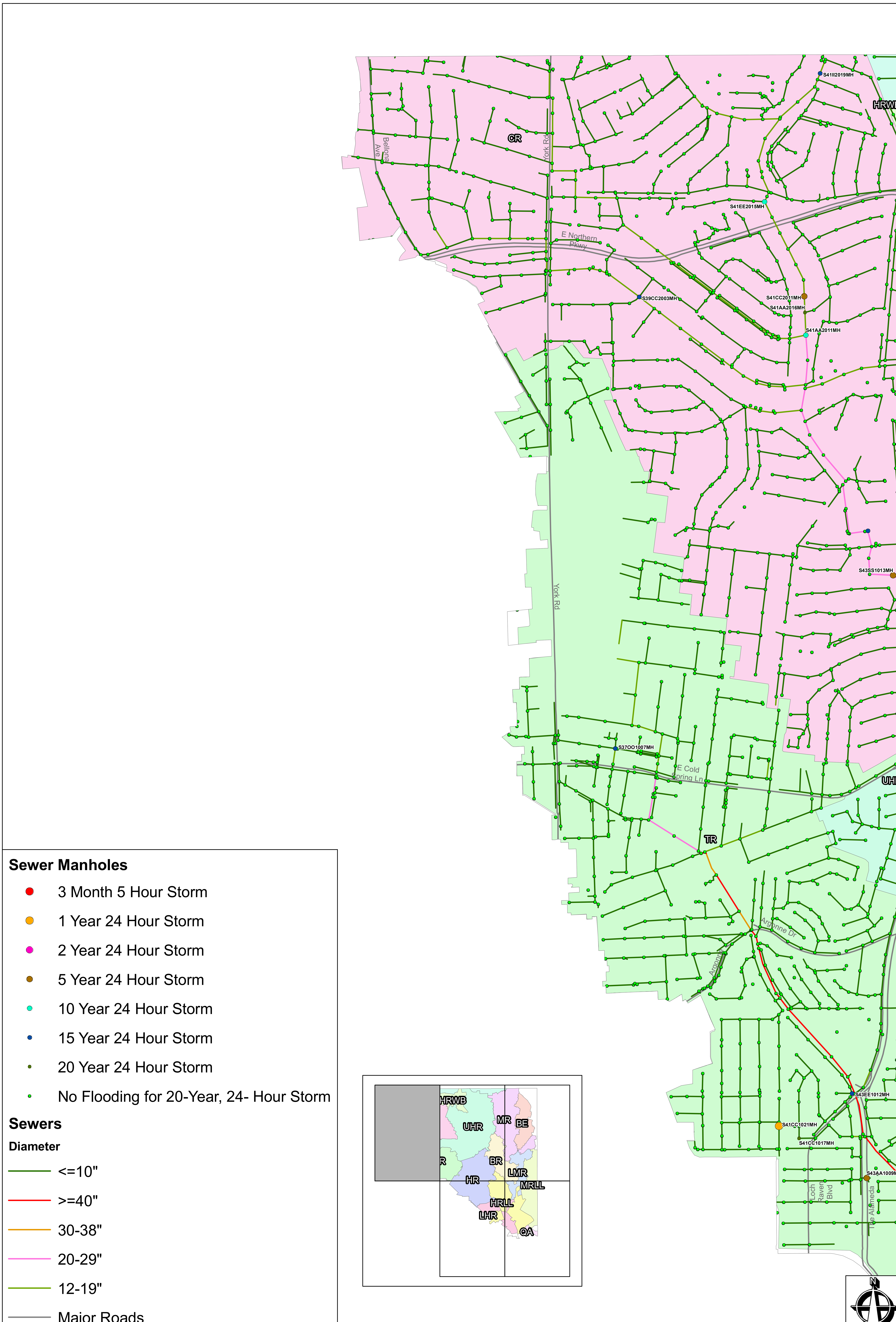
April 23, 2009

Scale: 1 inch = 0.25 miles

ModelSewers511.mxd J.Steurer 4/23/2009



Map 5.3.3A

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Storm Simulation Results (All Storms) Map 1 of 5

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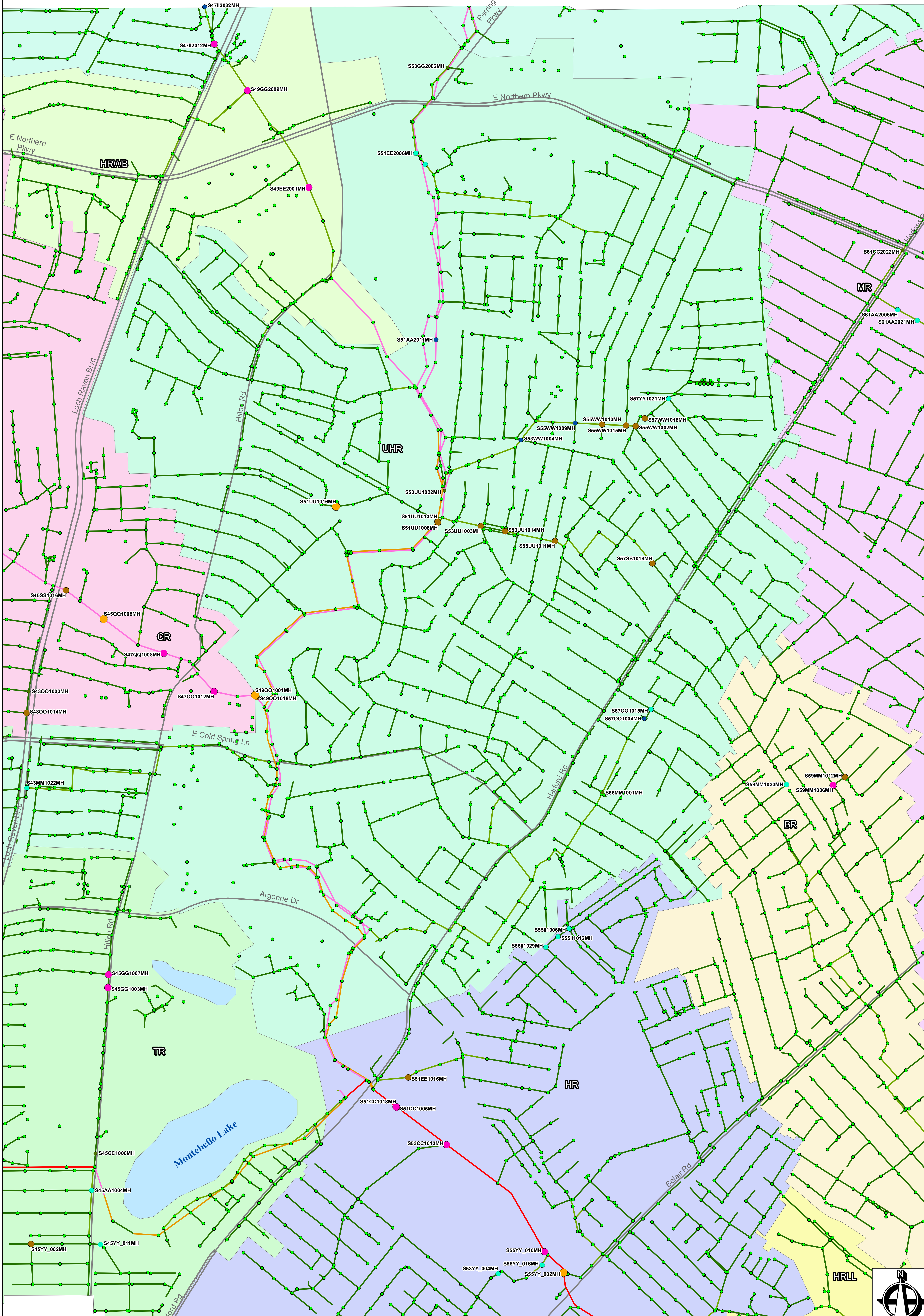
May 11, 2009

Scale: 1 inch = 0.113636 miles

StormSimulationResults.mxd J.Steurer 5/11/09



Map 5.3.3B

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

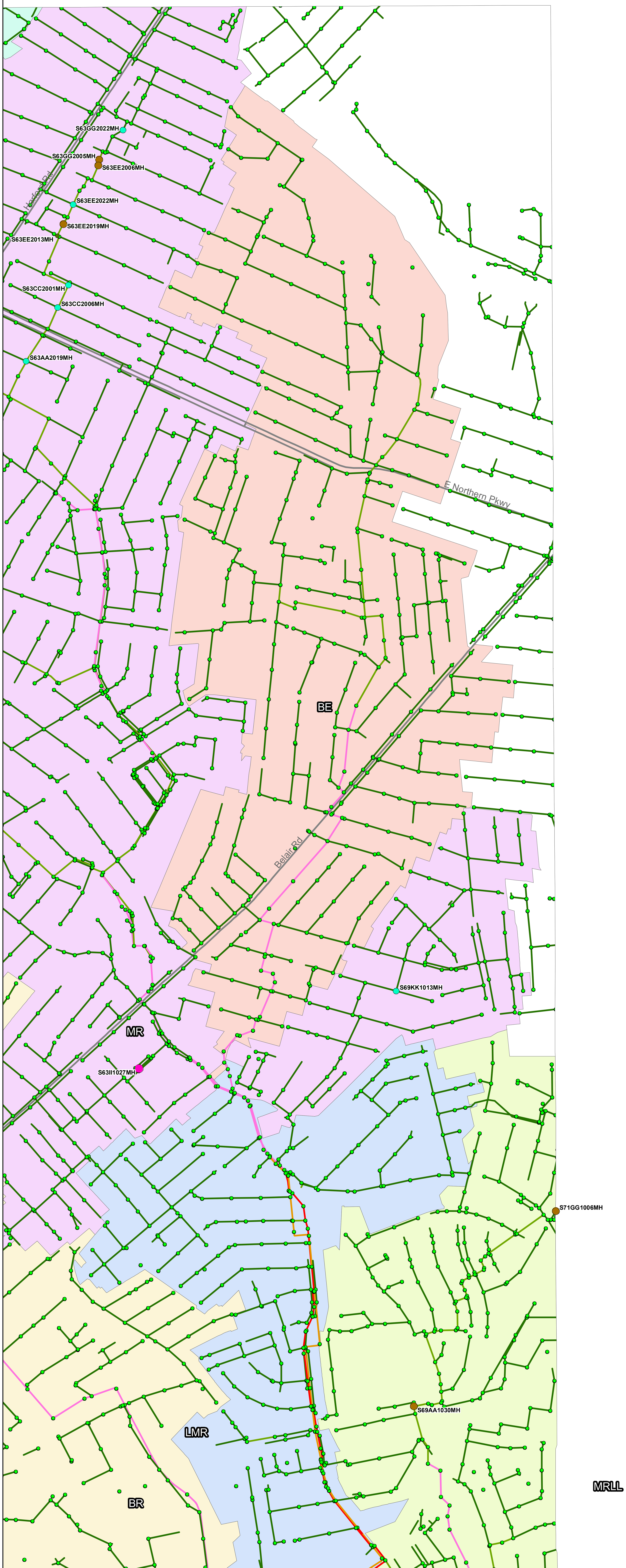
Herring Run Sewershed Storm Simulation Results (All Storms) Map 2 of 5

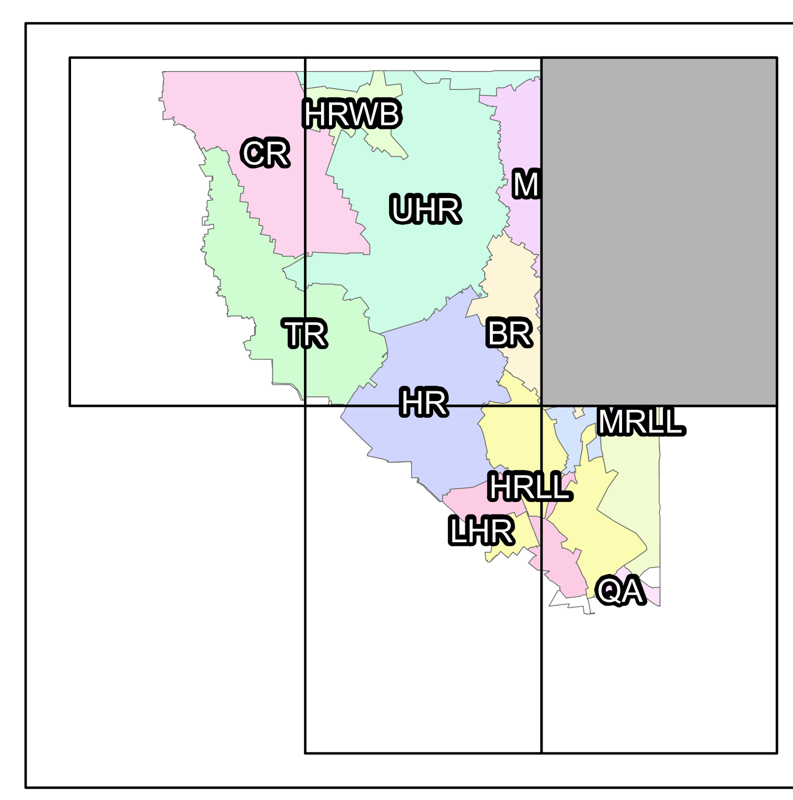
BLACK & VEATCH
Building a world of difference.

May 11, 2009

Scale: 1 inch = 0.113636 miles

StormSimulationResults.mxd J.Steurer 5/11/09





Sewer Manholes

- 3 Month 5 Hour Storm
- 1 Year 24 Hour Storm
- 2 Year 24 Hour Storm
- 5 Year 24 Hour Storm
- 10 Year 24 Hour Storm
- 15 Year 24 Hour Storm
- 20 Year 24 Hour Storm
- No Flooding for 20-Year, 24- Hour Storm

Sewers

Diameter

- <=10"
- >=40"
- 30-38"
- 20-29"
- 12-19"
- Major Roads

Map 5.3.3C

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Storm Simulation Results (All Storms) Map 3 of 5

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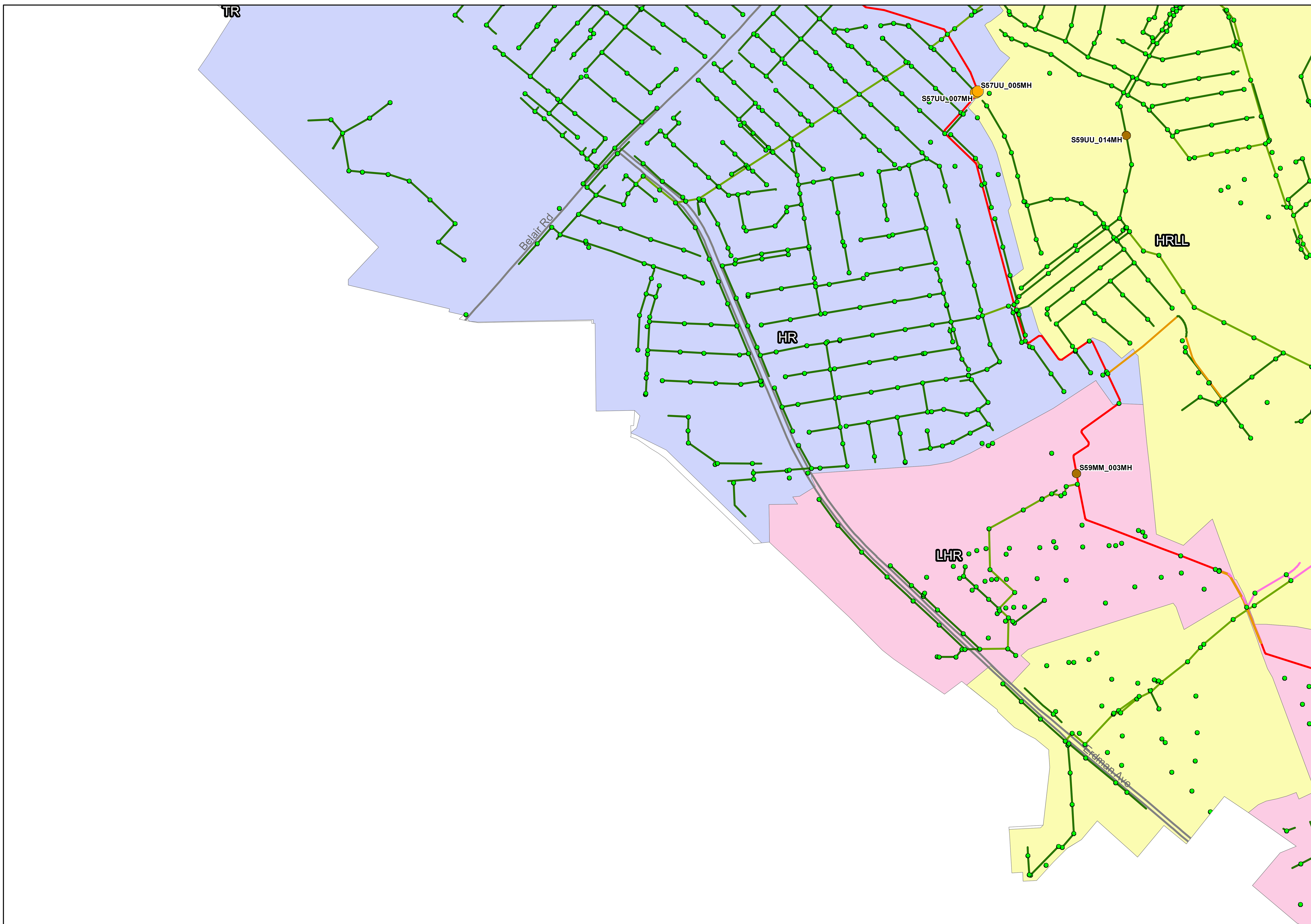
May 11, 2009

Scale: 1 inch = 0.113636 miles

StormSimulationResults.mxd J.Steurer 5/11/09



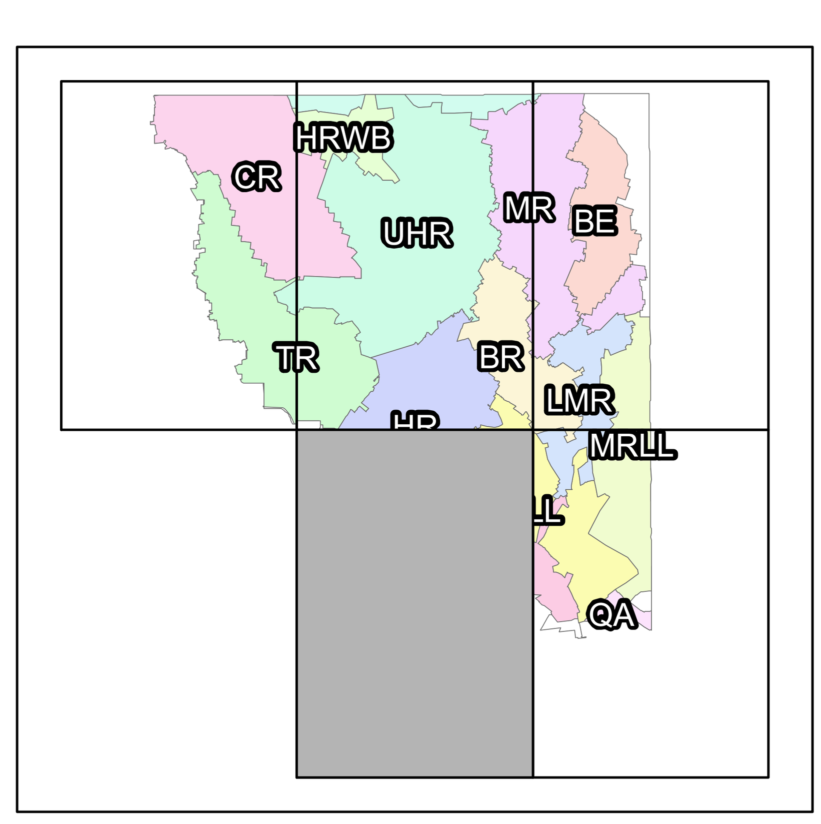
Sewer Manholes

- 3 Month 5 Hour Storm
- 1 Year 24 Hour Storm
- 2 Year 24 Hour Storm
- 5 Year 24 Hour Storm
- 10 Year 24 Hour Storm
- 15 Year 24 Hour Storm
- 20 Year 24 Hour Storm
- No Flooding for 20-Year, 24- Hour Storm

Sewers

Diameter

- <=10"
- >=40"
- 30-38"
- 20-29"
- 12-19"
- Major Roads



Map 5.3.3D

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Storm Simulation Results (All Storms) Map 4 of 5

BLACK & VEATCH
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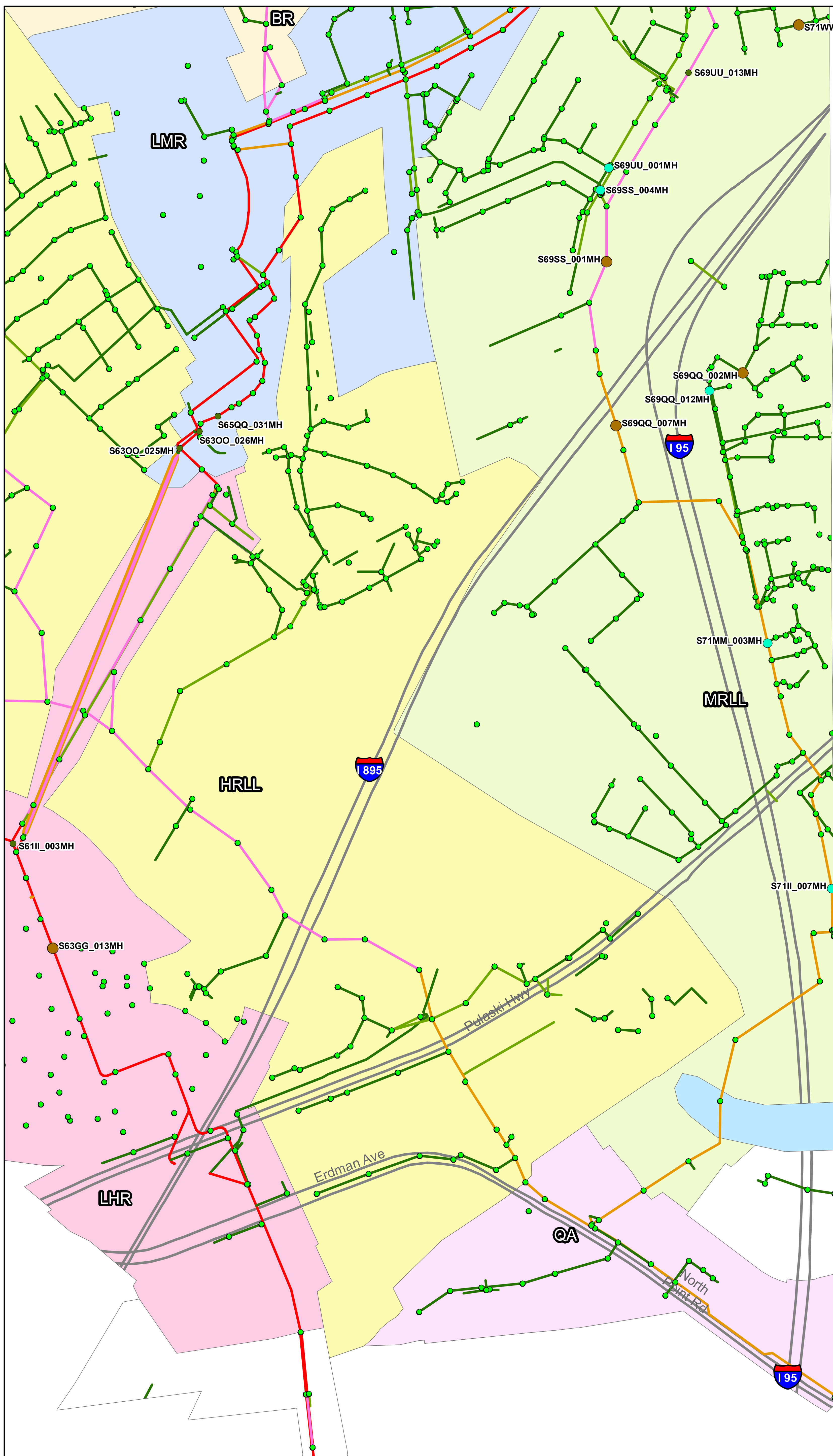
May 11, 2009

Scale: 1 inch = 0.113636 miles

StormSimulationResults.mxd J.Steurer 5/11/09



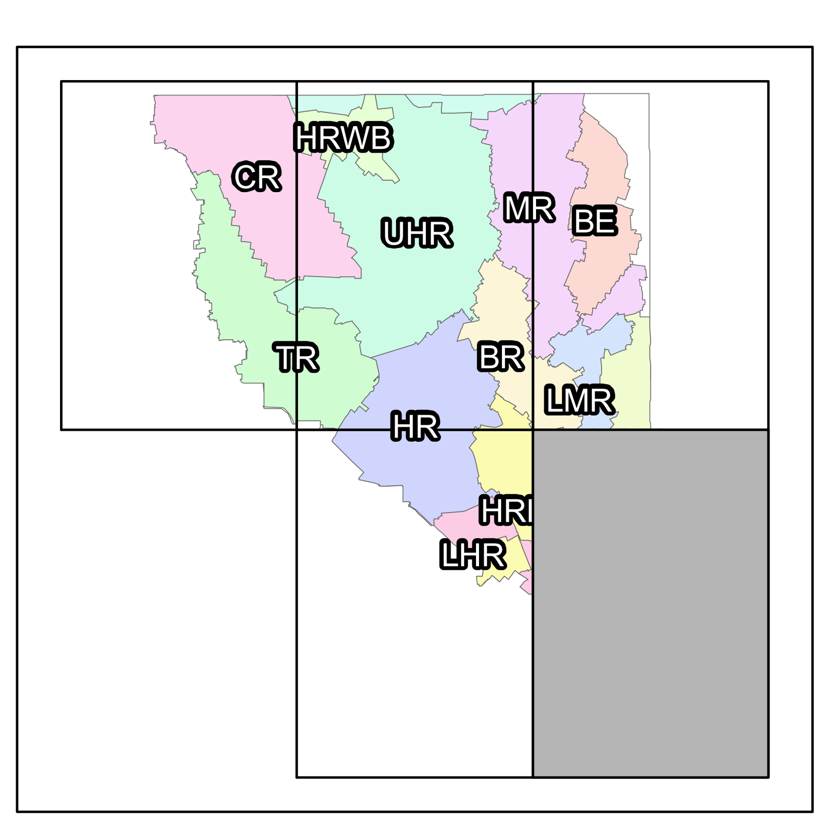
Sewer Manholes

- 3 Month 5 Hour Storm
- 1 Year 24 Hour Storm
- 2 Year 24 Hour Storm
- 5 Year 24 Hour Storm
- 10 Year 24 Hour Storm
- 15 Year 24 Hour Storm
- 20 Year 24 Hour Storm
- No Flooding for 20-Year, 24- Hour Storm

Sewers

Diameter

- <=10"
- >=40"
- 30-38"
- 20-29"
- 12-19"
- Major Roads



Map 5.3.3E

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Storm Simulation Results (All Storms) Map 5 of 5

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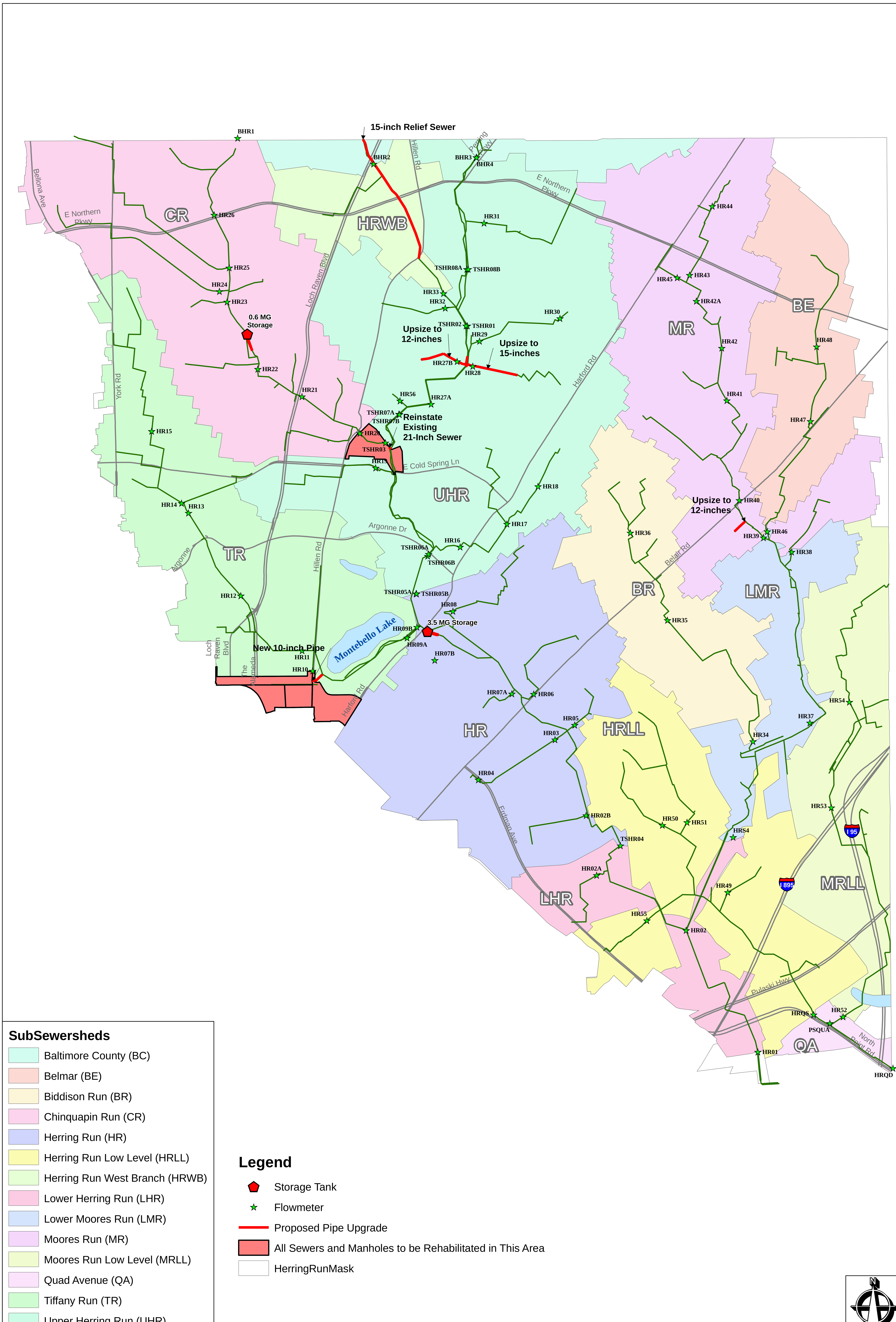
May 11, 2009

Scale: 1 inch = 0.113636 miles

StormSimulationResults.mxd J.Steurer 5/11/09



Map 5.4.1

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Alternative Analysis (2-year Storm)

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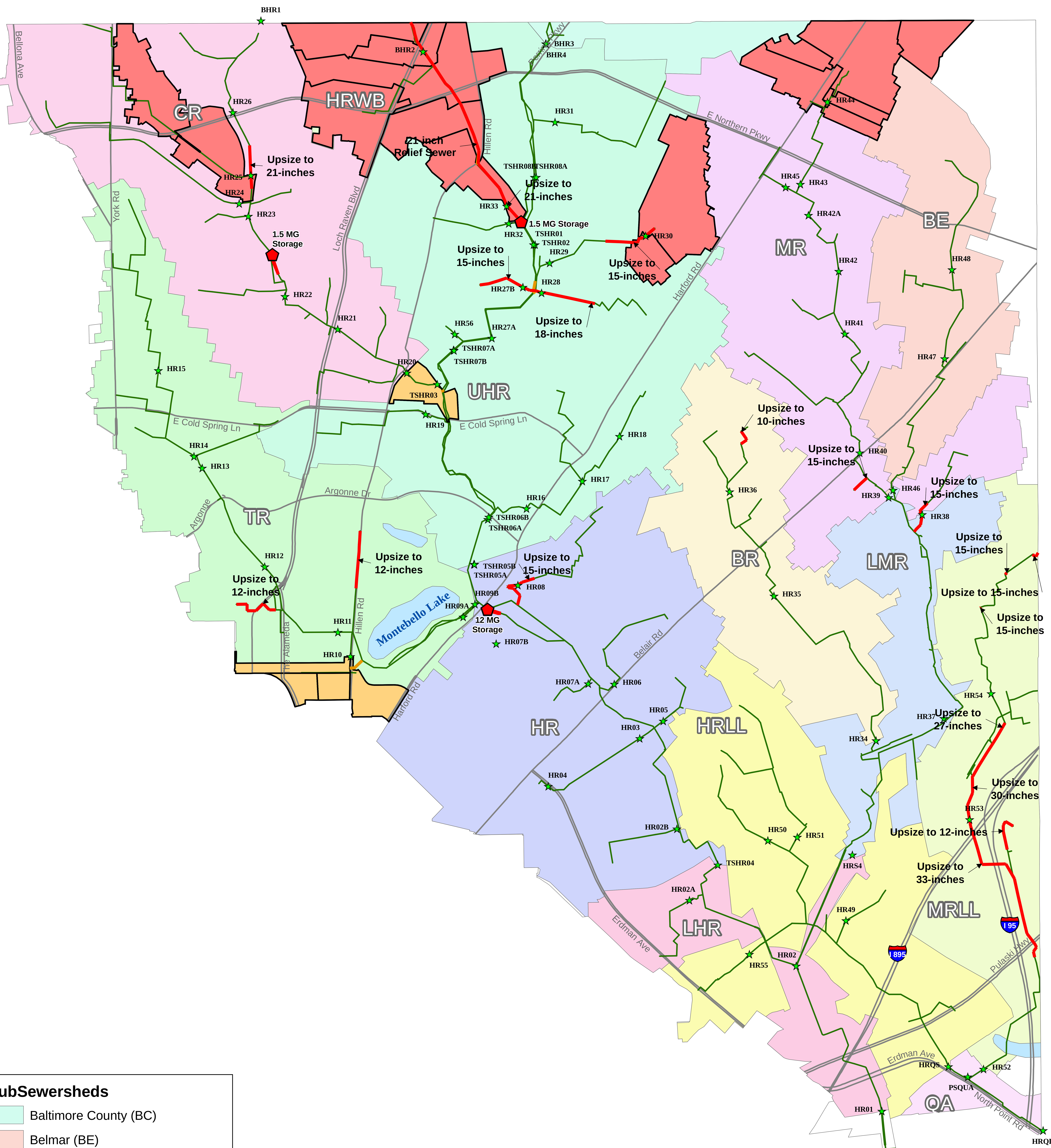
June 23, 2009

Scale: 1 inch = 0.25 miles

Improvements2year.mxd A. Black 6/23/2009



SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Legend

- Flowmeter
- Storage Tank
- Proposed Pipe Upgrade
- Previous Pipe Upgrade
- Previous Storm Rehabilitation Improvements
- All Sewers and Manholes to be Rehabilitated in This Area

Map 5.4.2

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Alternative Analysis (5-year Storm)

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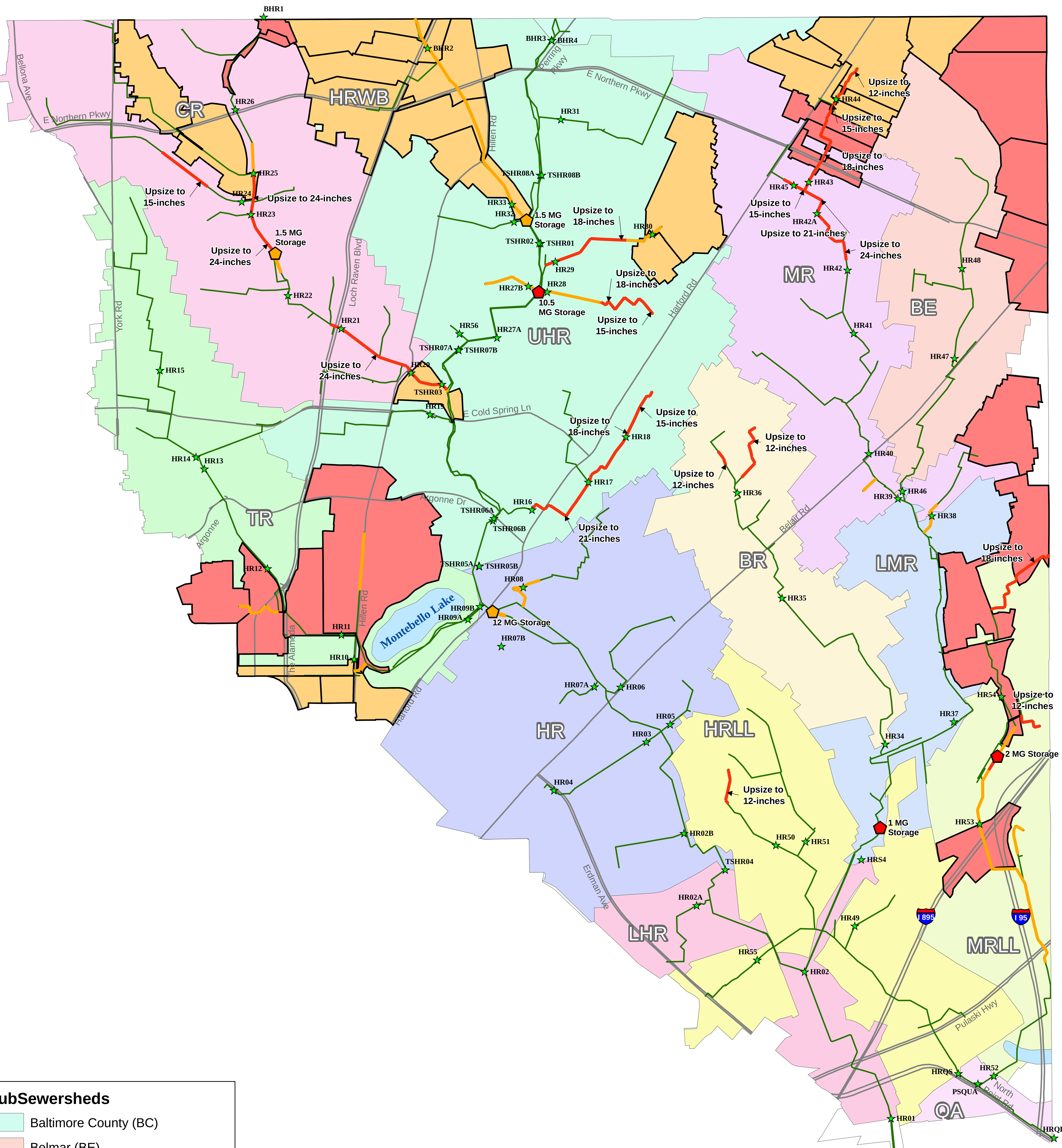
June 23, 2009

Scale: 1 inch = 0.25 miles

Improvements5year.mxd A. Black 6/23/2009



SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Legend

- Flowmeter
- New Storage
- Previous Storage
- Proposed Pipe Upgrade
- Previous Pipe Upgrade
- Previous Stormwater Rehabilitation
- All Sewers and Manholes to be Rehabilitated in This Area

Map 5.4.3

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Alternative Analysis (10-year Storm)

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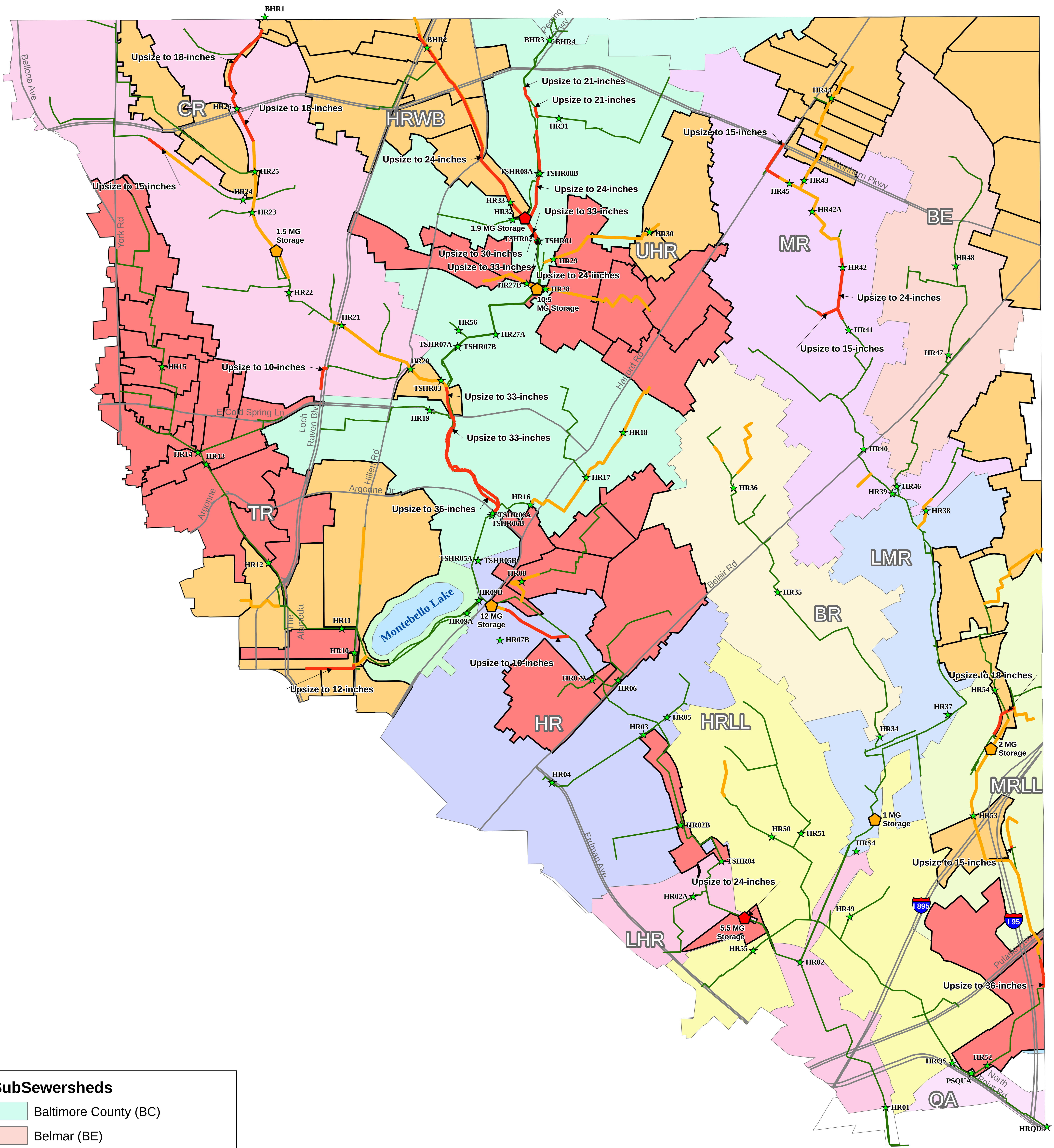
June 23, 2009

Scale: 1 inch = 0.25 miles

Improvements10year.mxd A. Black 6/23/2009



SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Legend

- Flowmeter
- Storage Tank
- Previous Storage
- Proposed Pipe Upgrade
- Previous Pipe Upgrade
- Previous Stormwater Rehabilitation
- All Sewers and Manholes to be Rehabilitated in This Area

Map 5.4.4

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Alternative Analysis (15-year Storm)

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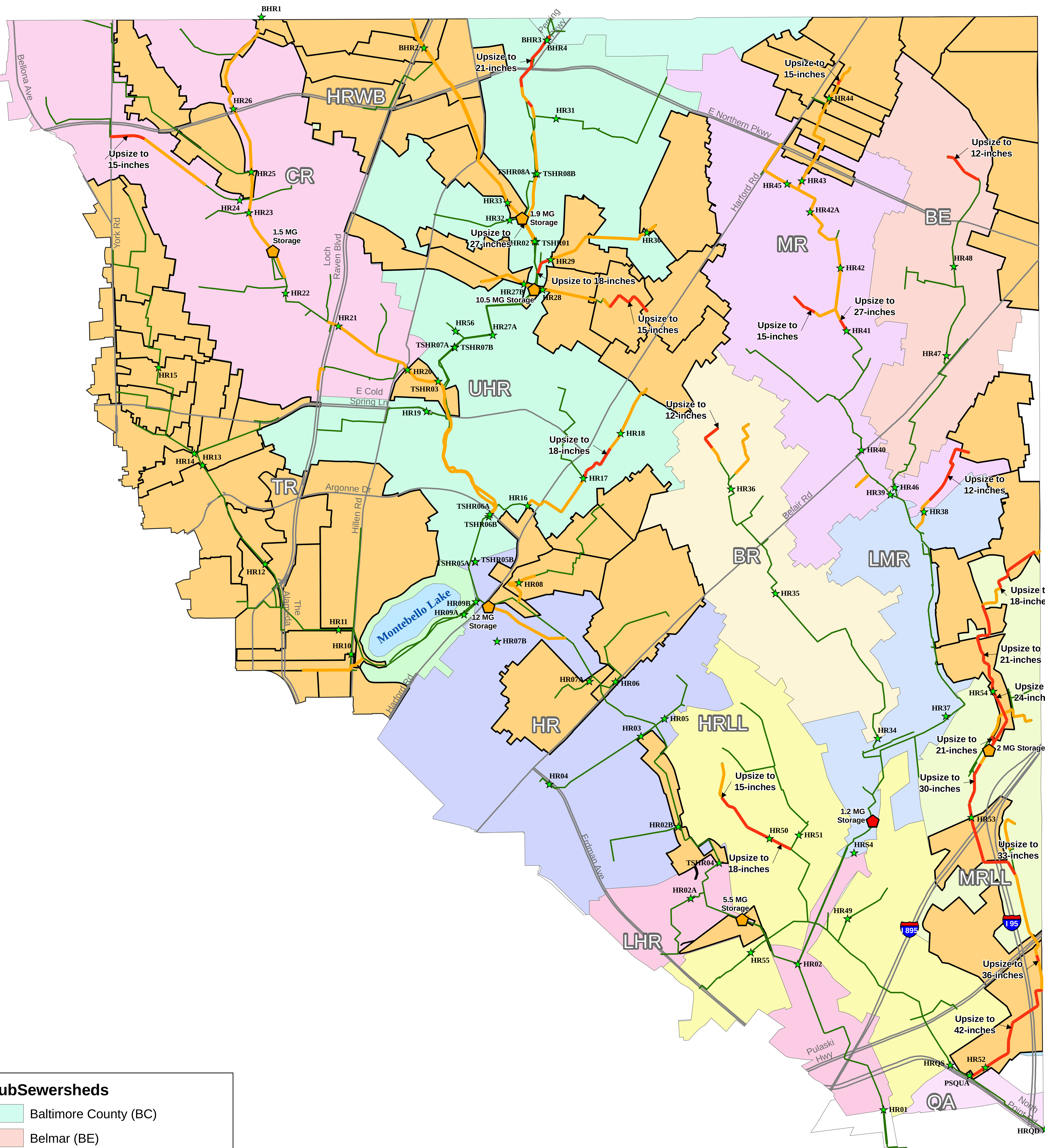
June 23, 2009

Scale: 1 inch = 0.25 miles

Improvements15year.mxd A. Black 6/23/2009



SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Legend

- Flowmeter
- Storage Tank
- Previous Storage
- Proposed Pipe Upgrade
- Previous Pipe Upgrade
- Previous Stormwater Rehabilitation
- All Sewers and Manholes to be Rehabilitated in This Area

Map 5.4.5

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Alternative Analysis (20-year Storm)

BLACK & VEATCH
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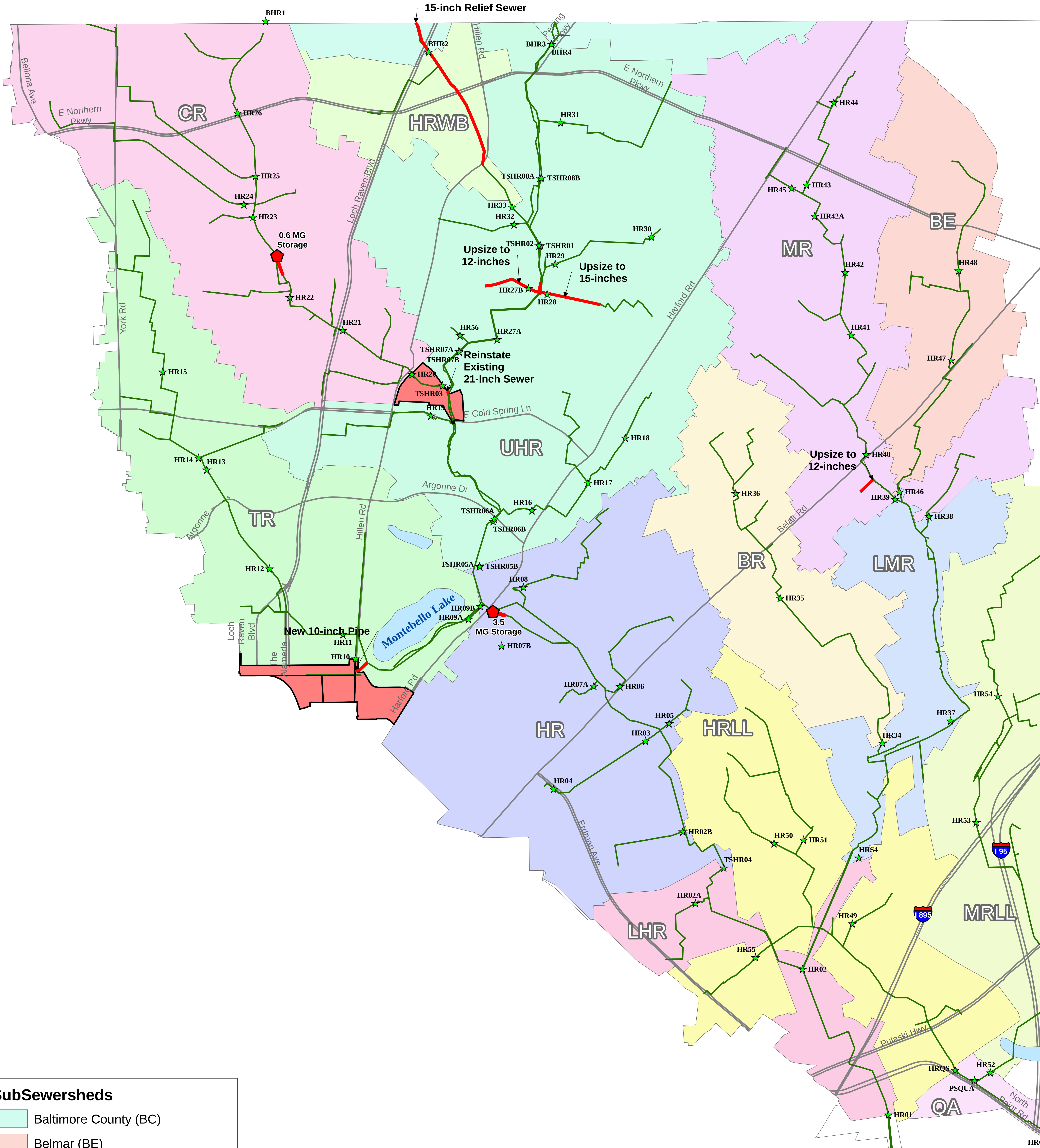
June 23, 2009

Scale: 1 inch = 0.25 miles

Improvements20year.mxd A. Black 6/23/2009



SubSewersheds

- Baltimore County (BC)
- Belmar (BE)
- Biddison Run (BR)
- Chinquapin Run (CR)
- Herring Run (HR)
- Herring Run Low Level (HRLL)
- Herring Run West Branch (HRWB)
- Lower Herring Run (LHR)
- Lower Moores Run (LMR)
- Moores Run (MR)
- Moores Run Low Level (MRLL)
- Quad Avenue (QA)
- Tiffany Run (TR)
- Upper Herring Run (UHR)

Legend

- Flowmeter
- Storage Tank
- Proposed Pipe Upgrade
- All Sewers and Manholes to be Rehabilitated in This Area

Map 7.2.3

CITY OF BALTIMORE 1797

Project 1001 - Herring Run Collection System Evaluation and Sewershed Plan

Herring Run Sewershed Recommended Hydraulic Improvements

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Scale: 1 inch = 0.25 miles

ImprovementsZyear.mxd A. Black 6/23/2009